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SOME ENGINEERING ASPECTS OF CAST IRON.

BY DR. RICHARD MOLDENKE.*

(*November 14, 1922.*)

Mr. President, and Members of the New England Water Works Association: It gives me great pleasure to speak to brother engineers this afternoon, on a subject which has proven my life work. Yet I also feel a little trepidation in speaking to you, as I do not see very many foundrymen present, but rather the consumers of the product the foundryman makes.

The investigation on test bar values which your President spoke about is not completed as yet, but it has brought out some interesting side lights in connection with the manufacture and use of cast-iron pipe. I will try this afternoon to give you a little more of the general aspect of the situation, and then draw conclusions as to the future of this work.

You are all familiar with cast iron, and I must take up first what seem to me to be the modern tendencies in the manufacture of the product. We strike at once the unfortunate situation that the dollar rules. In other words, labor has gone up to such an extent that the foundryman is forced to get more tonnage per productive man, otherwise the cost of the product goes beyond all reason. That, of course, in turn brings out the introduction of machinery, the replacement of hand labor by mechanical operation, and also from your standpoint that you compel the foundryman to cut costs farther than he has ever done. So that the man who produces must get more from the man whom he employs, and the man who buys must make a ton of iron go farther than it ever went before. It is this modern tendency, as we see it now, that is leading to what I hope in the end will be the coöperation of producer and consumer for the good of all concerned.

Let us look, first of all, at some of the requirements that are involved in this situation. Take the requirements of the consumer. He wants quality in his work, must have the castings and his pipe machinable. The foundrymen can easily give you stronger and harder material, but it is not so easy to give you quality combined with ease of machining and softness.

* Of Watchung, N. J.

Here we at once strike the difference between the practice as we have it in the United States and as they have it in Europe. We aim here almost entirely at making castings which will machine easily, because the cost of our labor is so high and we cannot afford to lose castings because they are too hard. On the other side of the water they work differently. They make the quality of the material that goes into the castings suit the purpose intended, no matter whether it machines well or not. This distinction is apt, in our export trade, to hurt us, because the uninitiated sees the high strength as they have it in England and compares it with our lower strength, and may give his order where he thinks he gets the best material.

We are looking now from the consumer's standpoint to a much greater accuracy in dimensioning. The old way in the foundry of rapping the pattern hard so as to draw it easily, does not go any more. We have to get our castings more accurate, our weights more exact, so that if we buy by the pound we can get the quantities we are after.

The consumer requires a much greater freedom from defects than was formerly the case. Anything which can be done along this line will be distinctly in the right direction. You have to reckon with so many factors when pipe is laid in the ground that it has simply got to be right, otherwise it proves an expensive proposition. Therefore, you are working now towards stricter specification limits, and will thus force the pipe manufacturer to greater care in making what you need. That, I think, is right and proper. The manufacturer who measures up to the times is perfectly willing to work under stricter specifications, provided he is paid for the results. And that, unfortunately, is the place where it hurts.

Let us look at the requirements of the man who makes the castings. He looks for two things; to render perfect the molds that his men make to pour the iron into, and to increase the number of molds that each man makes. The great desideratum in the foundry is that every mold made shall count. It is poor economy to have a molder make 125 molds a day and lose twenty-five of them because they were poorly made. The aim of the foundryman, therefore, is to make his molds as quickly, but also as good as he can, so that he has the least loss in defective castings. Hence, he is becoming more critical as to the mounting of the patterns, so that he may not lose castings, but make them as cheaply and as accurately as he can. Similarly in the selection of molding machines, the foundryman is getting much more careful now to pick out the particular machine that will do a given job best. All of this helps to ease production costs and enables him to give you pipe at reasonable figure.

The next requirement of the producer is a study of his materials. There is a very serious question which has been struck by the investigations Mr. Barbour spoke about. We are not getting the quality of pig iron today that we used to. The blast furnaces are forcing production, and where formerly 250 tons a day was considered a mighty good production, today it is 450 up to 600 tons, and the product is bound to suffer.

I remember way back in my early foundry days, that right here in Boston, before the New England Foundrymen's Association, I presented the idea of testing the pig iron for quality so that when a foundryman buys pig iron he may know what he is getting. But pig iron men objected too strongly. I hope, however, that sometime this will come, so that pig iron may be made under conditions which will pass a good material through the foundry into your pipe.

The study of foundry materials is being undertaken now very energetically, and the start has been made by a molding sand research committee which is digging very carefully into the question of the sand that is used in making your pipe and other castings.

We can extend the idea a little further and carry research work into the metallurgical processes in the foundry, such as for cupola melting.

Then comes the question of more attention to the collateral issues in the replacement of manual labor by machinery. The molding machine has been developed tremendously and yet some of the things that go with it have hardly been touched upon. Formerly when a man made, say 75 molds daily it was considered a good day's work; today he may make by a machine almost three hundred. I have noticed, however, that formerly when a man made a mold and put it down on the floor, then made another and put that down he had to go back and forth say seventy-five times with the molds and back and forth perhaps twenty-five times more with the ladle of molten iron to pour these molds; whereas today he has to walk three hundred times, plus, which is not a good thing for the molder by any means. So that in the study of the development of our work we have not given proper attention to these smaller issues that go to round out a great success, and this will have to come.

A uniform and discriminating cost system comes next. If the man who makes pipe does not know his costs properly, he will come into the market and bid too low to get contracts. Then you who get the pipe will find that he has, to come out even, skimped here and there, and a poor product is the result. I look for a development in cost systems, which will make them simple, and yield all the necessary information required. The result will be that those who are making pipe will be encouraged to do their best because they will feel safe on the outcome.

Finally, as one of the necessities of both pipe producer and consumer, I will urge the formation of a research association to study your problems for the good of all concerned without hurting the individual interests of any one.

A very interesting thing developed in Germany during the war, and which I afterwards had occasion to see. They were so hard pressed for fuel that they established fuel utilization centers. Every manufacturing district had a little bureau established and supported by everybody that was using coal, to study its economical utilization for manufacturing purposes. I conferred with the head of one of these heat utilization centers

sometime ago, and found that the results had been wonderful. They would study the practice of each establishment in the region; show where coal could be saved, and if one plant had very good results and another did not, they would instruct them properly. The consequence was that it cut the coal consumption down tremendously.

We need exactly the same thing in the foundry industry. The car wheel people have such a research association. The steel casting men have a small research association that has done wonders in working out standards for their sand, their smelting, and other processes. I would recommend very strongly that research be taken up for pipe, inasmuch as the investigations that have been carried on these last two years have shown the necessity for such a development. And I should like to see this research taken up not only by the foundrymen, but also that the engineers should add their quota by forming a committee, which would act as an advisory board to the makers of pipe, so that those who make the product you buy may know what you want.

The question of specifications comes in here. I remember that before the war when I was over on the other side of the water with one of our manufacturers of pipe, and we interviewed the European pipe manufacturers of England, Belgium, France and Germany, we found quite a feeling for coöperation in respect to eventual international specifications for cast-iron pipe, so that in the non-producing fields of the world, all bidders for work would be on the same basis. This, of course, has been delayed by the war, but we hope that some day it will be taken up again and worked out to a sucessful conclusion.

In Washington our friend Mr. Hoover is doing some mighty good work in the industrial field by trying to eliminate a lot of unnecessary sizes and items of manufactured product.

The future of the cast iron lies in working for quality; to get castings with metal of the greatest density, strength and resilience, so far as cast iron can be made to conform to these conditions, and yet to keep the machinability as good as may be required.

There is one great difficulty, however, standing in the way, and that is the constantly increasing sulphur in our scrap. When I went into the foundry industry some thirty odd years ago, our scrap contained about .05 sulphur. Ten years later it was .08; later it rose to .12 and just before the war it was .14. During the war castings were made with .32 sulphur. To-day you can go all over the country and find castings made in jobbing shops where they use scrap undiscriminatingly, that run between .20 to.26 in sulphur regularly. This is a pretty serious situation.

You will recal in your own work that sulphur is the great danger in pipe subjected to water-hammer. It means, therefore, that we need to be on the watch for the sulphur in the scrap which inevitably gets back into the foundries. While foundrymen should use more than 50 per cent. pig iron in their mixtures, excess of scrap will be used where scrap is cheap

and pig iron is dear. But, fortunately, we have three ways out if we will use them. One is to use more pig to dilute the sulphur. The second is to use the basic hearth electric furnace, which probably will be very slow in coming into use on account of the high first cost. The third is the desulphurizing of molten metal in the ladle which is now being done on the other side of the water successfully, the sulphur being almost cut in half.

If you study the analysis of a piece of cast iron, you will see that it is practically steel plus a lot of graphite.

The graphite is scattered in little crystals all through the mass and weakens the iron because it breaks the continuity of the steely mass. On the other hand, it is also a lubricant for the tool that cuts through the cast iron in machining it. If you can make the size of the graphite crystals smaller, and reduce their number, you are making stronger material. This is why steel scrap is added to cast-iron mixtures. It cuts down the carbon content of the metal.

If you remember that cast iron is steel plus graphite, then you can see how improvements can be made. If you can hold the same combined carbon and reduce the graphite a stronger material will result. If you can add to the steel portion of cast iron such metals as nickel or chromium, or if you can reduce the phosphorus and sulphur by special treatment, you are going to strengthen the resulting material. There is a very profitable field open for men who make castings, if they will only study what they are working with.

Now, if you, who know what real steel is, will just imagine for a minute that in cast iron you have the steely portion containing, let us say, 1 per cent. of phosphorus. This is ten times the amount allowable in good steel and still such a cast iron is a serviceable product though not good when subject to shock.

Now, the silicon, sulphur, phosphorus and manganese content in cast iron all have their effect on the condition the carbon therein is going to take. Whether it is going to be high in graphite or in combined carbon. The more silicon the more graphite. High phosphorus and sulphur make for more combined carbon.

It is this situation that accounts for the thought you had in mind when desiring to put into the specifications a chemical composition requirement.

But there is one chemical item that is generally forgotten, and it happens that there is often times something in iron which is bad. This is a dissolved oxide of iron. When we get an iron that breaks easily but with an otherwise good composition, there is something else present which ordinary chemical analysis does not show. This dissolved oxide of iron is probably ten times as powerful for evi as sulphur. In one case I have known of such oxidized molten iron, the metal though white hot set so fast that it would not go into the mold at all, yet it only contained $^{3}/_{100}$ of 1 per cent. of oxygen. This is the reason why you cannot specify a chemical com-

position and be sure of the result. The iron that comes into any foundry is always more or less oxidized; in fact, this is the great difference in quality between pig iron on the one side and scrap on the other. Pig iron and scrap may have the identical composition, yet pig iron is made in the reducing atmosphere of a blast furnace, while scrap is material that has been melted in an oxidizing atmosphere in the foundry cupola. It makes a big difference whether you use 10 per cent. pig and 90 per cent. scrap, or 90 per cent. pig and 10 per cent. scrap even with the same composition in the castings in each case. This explains why it is impossible to use chemical specifications safely.

The upshot of the matter is that you should give your attention specially to specifying the physical characteristics of the metal you want, and then let the foundrymen give you the right composition metal to do it.

As far as physical properties are concerned, these mean quite a number of cast-iron varieties. You are more especially interested, however, in only a few of the characteristics. One of them is the hardness of the iron. You want the iron reasonably soft. Then you are interested in interior shrinkages. There is a most important matter.

When iron is in the molten state, and comes into the solid state as in gray iron, it is reduced in volume $5\frac{1}{2}$ per cent.; when as white iron, which is quite hard iron, it is reduced in volume more than 12 per cent. When molten iron is poured into the mold, the metal first sets all around against the mold surfaces because they are cold and damp; or, in the case of pipe, are warm and dry. Since the iron will set solid against the sides, and unless some more molten iron feeds in to care for the volume reduction, you are going to have a hole, or at least a spongy material, in the center. That is what we call "interior shrinkage."

Now, fortunately, pipe is one of the ideal castings so far as pouring it is concerned. You pour from the top, and the iron has a chance to begin to set as it rises in the mold, and feeds itself as the mold fills to the top.

Suppose, however, your metal is bad — that it is oxidised too much. Then as the mold fills up the gates freeze and the iron within the mold setting requires some fresh metal and cannot get it. Then you have pipe wfth a spongy interior. Such pipe when in service corrodes faster than the good, sound article. Hence, the shrinkage problem is a very big one for the pipe maker.

Shrinkage brings with it another physical characteristic, and that is segregation. If the iron remains fluid a long time, and the setting action against the mold takes place slowly, the iron phosphide and iron sulphides present having a lower freezing point, will stay liquid a little longer and will go inward, thus making the center of a heavy section much higher in the two elements in question than the outer portions.

The strength of the iron going into pipe is highly important. It is desired to have an iron which is strong and yet which bends with a good deflection. Such iron is also resilient and can withstand considerable shock.

Then a final point among the physical properties of cast iron for pipe is the question of the resistance to corrosion. This is a subject all by itself, and which is best discussed by those who have made a special study of the matter.

This brings the subject down to the possible development in the pipe problem as you find it today, and here we find limitations on the side of the consumer as well as the producer.

The very first limitation you find hampering the purchase of pipe is the taxpayer. He wants to have the money spent reach just as far as it can when purchasing pipe. It means that the man who makes the pipe can only use low-priced material to begin with. Hence the temptation to use as much scrap as possible with poor results.

The next limitation is that there is a lack of familiarity on the part of the consuming interests with foundry procedure outside the pipe shops. In other words, inspectors go out inspecting pipe, but there are few of them who know any more about general foundry operations than what they see in the pipe shop. The pipe manufacturer is very anxious to make a good product, but most of them are familiar only with the making of pipe and fittings. We all should know as much as possible about general foundry practice, because it helps us in whatever particular line we are in.

The next limitation of the consumer is engineering precaution. Your engineers try their very best to surround the selection of pipe by all the precautions they can. They use good factors of safety. They plan the water works carefully. Yet all these precautions are weakened by a number of things they cannot foresee. For instance, after the pipe has been laid and people start building houses along the new streets, they are introducing earth settling problems that may cause breaks in the best of pipe systems. A trolley line may be put through a district where there was never one before, and there results rapid corrosion by electrolysis.

Then there is another serious matter, and that is a lack of proper discretion in the placing of pipe contracts with the foundry. I myself have for ten years been a member of one of the State Boards of New Jersey, and I know what it means to advertise for supplies. By law the man who makes the lowest bid is entitled to the contract. The trouble that results afterward in trying to make the contractor live up to the specifications you all know. If a new concern springs up and goes into pipe making, and that concern makes a lower bid than the experienced in the business, trouble is almost certain to eventuate. Bad metal will make good-looking pipe — on the outside, but between the two surfaces the metal may be full of shrinkage and segregation conditions.

Now the limitations on the side of the producer. Here again comes the question of competition. Foundrymen underbid each other and the successful man gets the contract. Thenh e tries to get by, the easiest way— which, of course, is not good for the parties of both parts.

Then another thing which affects the quality of the pipe made is the tonnage forced out of the plants. Two foundries having exactly the same sized cupola, one takes off twice as much metal as the other per hour, which shows that something is wrong. If you force an equipment, even in a foundry, you are rather certain to produce poor results. There are a number of works so situated that they have grown very fast. Their equipment has, however, not grown sufficiently fast with the growth of their orders. Hence this situation is one of the limitations of the producers.

Next comes another very important point, and that is the lack of realization on the part of the producer that he may have a splendidly organized engineering staff; he may have ample apparatus, and yet he may not have taken into consideration the metallurgical side of the enterprise. Suppose the foundryman equips his cupola with a mechanically very efficient charging device, so that he may operate very cheaply for this item of cost. He may, however, have forgotten that such devices may charge so unevenly that the molten metal out of that cupola is badly oxidized and hence of poor quality.

Then, finally there is the lack of coöperation between the consuming and the producing interests. The sooner the pipe consumers get together with the pipe makers through joint committees in research work, the quicker will all benefit by it.

I am closing by urging upon you the constant consideration of three points:— First that there is the necessity for every one interested keeping abreast with many lines of information. Second, that there is the necessity of studying each problem to discover the principles which are involved. You want to know why a thing is or should be done. Third, that there is the necessity of so shaping your operations that the principles which you have found involved are applied in the most practical and economical manner.

Discussion.

President Barbour. This talk of Dr. Moldenke's will at least emphasize one thing, and that is the difficulties which your Committee on Revision of Standard Specifications have been facing for ten years.

There are with us today some foundrymen, and we have a number of members thoroughly qualified to discuss the subject. The paper is now open for questions or discussion.

To give point to the discussion I may say a few words. You will notice that Dr. Moldenke has reached the conclusion that chemical specifications are not feasible. The Committee does not entirely agree with Dr. Moldenke on that point as yet, and I think that he will admit in the first place that sulphur should be specified.

He speaks of oxidation, and the fact that it nullifies chemical specifications, but in our opinion, that is hardly a justification for eliminating chemical specifications.

I rather hoped that Dr. Moldenke in his very modest talk — because he could talk all day and keep you interested — would touch a little more on the relation between flexure and breaking load. Your Committee in its tentative specification recommended that the breaking load be made 1 900 lb. minimum breaking load, and that at that point the deflexion should not be less than three-tenths of an inch. In Dr. Moldenke's early experiments made with the iron as he found it in the various foundries, he came to the conclusion that it would be impossible to meet that specification. The Committee then said, " Yes, that may be true with the iron now used in these foundries, but isn't it possible to make a better iron? Why not go back and see if you can, within commercial limits, develop a better iron?" And that has been the investigation which he has been carrying on during the last six months, the report of which is not yet in the hands of your Committee. We are hoping that we will be able to convince the foundrymen and Dr. Moldenke that it is possible to get an iron that will carry a breaking load of 1 900 lb. in our standard Association Works test bar in flexure, and a deflexion at that point of three-tenths of an inch, and we believe, I think, as a Committee — and we are trying to be fair to the foundry men and to the consumer — we believe that, if we were to put out a specification of that kind today and there were an order of sufficient size back of it, we would be able to get that iron today.

The subject is open for discussion, Gentlemen.

Dr. Moldenke. While I have expressed myself as objecting to the introduction of chemical requirements into the Standard Specifications for cast-iron pipe, in addition to the physical requirements necessary to insure proper strength, resilience and soundness of this class of material; yet I am not at all averse to the limitation of any element or elements likely to give trouble. In fact, now that we have a positive, practical and cheap means of reducing the sulphur content of molten iron in the ladle before pouring our pipe, I would rather welcome the limitation of this injurious element to a minimum sufficiently low to insure safety from suddenly applied shock — such as the water-hammer. Iron sulphide, in segregating inward as the metal sets, seems to form a network or thin layer separating the individual crystals of purer iron from each other. Iron sulphide being very weak, when subjected to shock will break readily and start cracks, with eventual failure of high sulphur pipe.

In the case of the general composition, however, it will be found that in order not to exclude serviceable pipe of all kinds, the limits for each element will have to be held so wide that no specially useful object will have been served in adding this burden to the troubles of the foundryman. There is no objection whatever in " recommending " a desired composition, but it should not be made obligatory.

The rather elaborate investigations which have now been concluded have — on the whole — been badly disappointing. Some of this can be laid to the inferiority of present-day materials purchased in the market.

Some also to poor shop practice in the foundries. Most of it, however, it appears to me is due to the inadequacy of the test bar used to indicate the quality of the metal going into pipe. I have, therefore, recommended that associated research work be undertaken by the producers and consumers jointly, so that no avenue of improvement might remain untraveled because we are not now aware of it. Much is known about steel as a material of construction, but cast iron still offers a great field for investigation with promise of considerable improvement.

Mr. F. B. Brown.* Mr. Chairman, I really don't know what I can add to what Dr. Moldenke has said. I have had the privilege of being a member of a committee which was appointed by the manufacturer to investigate the question of chemical and physical specifications for cast iron pipe. As has been intimated — I don't know whether it has been directly said — we felt that we should not conduct that with any of our own staff, and we secured the services of Dr. Moldenke, who conducted a great many tests, 600 or 700 tests, probably, in relation to the chemical specifications. Unfortunately, the results were negative. We could find, so far as our investigation went, that considering the elements which we took up, namely, silicon and sulphur, that there was no rational specification which we could draw in the matter of those two elements. We appreciated, of course, that there were a great many other factors in the formation of a casting besides sulphur and silicon. There was the question of the section of the metal, as Dr. Moldenke suggested. The chemical analysis would be perfectly good in a test casting an inch and a half thick which would be utterly worthless in a casting a half inch thick. That was one of the difficulties which your original or tentative specifications possessed. But broadly speaking there was a negative result as to chemical specifications.

In the relation between flexure and breaking load, Mr. Barbour says that those results are not in his hands, and I will not speak of them at all until they are in the committee's hands and have been discussed by them. But they unfortunately have been very much of the same character. Curiously enough they to a great extent contradict what our learned doctor has said in regard to the use of scrap. We took iron containing different amounts of silicon—for instance, we took $\frac{1}{4}$ per cent. silicon, and different percentages of scrap, and remelted them, say, with 20 per cent., 30 per cent., or 40 per cent. scrap. So far as the physical results obtained were concerned, no intelligent person can say that the addition of scrap added to or subtracted in any way from the quality of the bar.

Dr. Moldenke. The bar, but not of the pipe.

Mr. Brown. The bar is not a true criterion. The bar is a section 1×2. What pipe is under similar conditions? So far as the results of our investigation are concerned on that, I regret to say that they have not been productive.

* Superintendent Warren Foundry & Pipe Co., Phillipsburg, N. J.

I had hoped that with the opening up of experiments, putting the experiments in all these various foundries — they put them in eight or nine — that we would be able to at least arrive at an inkling of something that would give us a specification which would enable those who want to give their customers the right thing, to do so, and to cut out those who might try to get away with it.

In the matter of specifications generally, you gentlmen have a specification of your own, and the American Water Works has one of its own, yet as a manufacturer I want to say that during the last year the larger percentage of our work has been on bastard specifications. Now, it is a very good thing to get a right specification, but it is going to be futile to secure one that it not referred to by the water works engineers or by the managers more than the present one is. One of the big items of expense to all pipe foundries is the carrying of patterns for parts and for all the other paraphernalia connected with making special jobs because one city had them fifty years ago and perhaps wants to keep them, or because of the whim of some particular engineer, who wants to get up something which will bear his name.

Simplification and standardization of specifications, and a real adherence to them, is going to make a vast saving to us, and of course that will be a vast saving to our customers.

President Barbour. I think it should be recognized by this Association that we are greatly indebted to the manufacturers for their generous coöperation, and if anything I say as a member of this Standardization Committee suggests that there is any friction, I do not want to leave that impression.

I do want to say this, however, that while it may be that in the end we will come to leaving out the chemical specifications, those which we proposed five years ago would have admitted all the irons which Dr. Moldenke has tested, and would have barred out almost every iron disclosed by the analyses of broken pipe, of which Mr. McInnes has such a large number collected from Boston and other places. In other words, the tentative specification which we proposed would have thrown out a large majority of the pipes which have broken under working conditions in the City of Boston, and at the same time would have admitted all the irons with which Dr. Moldenke has had contact in his investigation. So, in my judgment, it still may be possible to set an outside limit for a chemical specification which will be of some value.

EXPERIENCE WITH THIRTY-FIVE YEAR OLD STEAM PUMP.

BY FRED O. STEVENS.

In 1885, a 1 500 000 gal.-Blake-duplex-compound pumping engine was installed as a part of the new water system for the town of Weymouth, Mass. About two years later a Deane pump of the same capacity and similar design was started, to work with the Blake at times of excessive demand and as a reserve in case of a breakdown.

While the total amount of water pumped per year in these early days was relatively small, the service was unmetered and the demand during certain hours in the lawn-hose season was in excess of the combined capacity of both pumps, and often nearly exhausted the available storage. In an attempt to keep up with this demand it was customary to run both pumps at a speed far beyond that for which they were designed, and at a delivery rate practically equal to the maximum capacity of the suction line, which is about 2 700 ft. long.

This speeding up, and occasional deficiency of water on the suction end, must have subjected the pumps to severe shocks and strains which may or may not have contributed to the final breakdown of the units. However, they carried on under these conditions for twenty-nine years and under better conditions for six years more, before serious trouble was experienced.

The writer assumed management of the system in 1914, and was able to meter 500 services before the summer demand reached its maximum, with the result that we got through the season with pumps running at normal speed. In 1915, 1 000 meters were added and by 1916 with the system 50 per cent. metered, it was possible to handle the peak load with one pump.

Owing to their low efficiency the writer was opposed to expending any large amount of money for overhauling these units, but instead planned to replace them with modern steam pumps. By this time, however, war troubles were upon us and it was decided to get along with the old outfit until conditions of prices, labor and transportation were back to normal.

All went well until the spring of 1920 when a crack developed in one of the high pressure cylinders of the Deane pump. This cylinder had been previously rebored, and it was found that there was a scant $\frac{3}{8}$in. of metal left. A new cylinder was rushed through and with some minor repairs the unit was again put in service. The writer, however, after a careful examination at the time that the steam end was dismantled, felt that it would be taking too long chances to depend upon this unit for its share of the summer's work, and immediately got out specifications and let a contract for a

motor-driven centrifugal unit of the same capacity to be placed in the basement and connected with the suction and discharge of the old steam pump so that electric and steam could work, either together or separately.

Electric drive was chosen, mainly because the unit could apparently be delivered much quicker than steam pump of same capacity, and could be installed without interfering with the operation of the existing plant. It was also determined, however, that operating costs, including interest and depreciation, would break about even with those for a new steam plant.

Delivery on electric unit was first promised for July, but, owing to labor troubles, delivery of motor was soon changed to October. The summer of 1920 was one of exceptionally heavy demand on the entire system, owing to unusual consumption by manufacturers and the position of those responsible for the pumping plant was, to say the least, an uncomfortable one.

On August 12 the expected happened, in an altogether unexpected quarter. The Blake pump, which was in the better condition, and upon which we placed our chief reliance, developed a crack in the suction chamber just above the bed-plate flange. As the suction lift was high at this time of year, the amount of air taken through this crack made it impossible to run the pump without severe shock and vibration at each revolution.

To take down this unit and substitute a new chamber or attempt a weld by the acetylene process would have meant a long period with only the old Deane pump, looked upon as a cripple, between us and complete disaster. The game was then, to keep both cripples in some kind of working condition and pray for the arrival of the electrical equipment.

An electric welding company thought that they could weld the casting in place, and while the writer was skeptical he was in a position to try anything and told them to go ahead. When the casting was drilled for the electric weld it was found that in places along the fracture there was a scant quarter inch of metal.

This weld was, in a measure, successful, in that it did strengthen the casting and in that way made it possible to get through the season without a complete breakdown, but it was neither water nor air tight, the pump taking practically as much air as before.

We then built a form on the foundation, the entire length of the suction chamber, about four inches away from it and extending about three inches above the crack, and into the space between the form and the casting poured enough hot asphalt to fill it completely, at the same time turning the pump over to create a partial vacuum in the chamber.

After allowing a few minutes for cooling, the pump was started and worked very smoothly. Vibration and the action of water weakened this patch in time, so that it was necessary, about once a week, to heat the casting and asphalt with a blow torch to get a new bond.

Troubles never come singly, however, and it was but a short time before the Deane pump began to take air and a crack was found in its suction chamber. This chamber extended down below the top of the foundation

about ten inches into a recess in the masonry with a clearance of about one-and one-half inches between the casting and the stone work.

The crack was in this inaccessible section and it was necessary, in order to get at it, to go into the basement and drill and pick an inclined passage-way up through the masonry. It was then possible for a man with a small hand to apply hot asphalt to the crack with a two-inch brush, which helped matters considerably, but we were never able to get this pump running as smoothly as the other.

However, we crippled along quite successfully until December 1, when, just as the station was shutting down for the night, the engineer reported that the crack in the Blake pump was extending around the suction chamber and showing up on the other side.

Things looked rather dark just then but we applied the hot asphalt as first aid and set out to find some kind of a second hand unit that could be rushed into service immediately. Having given up hopes of getting the new motor before the first of the year, we had for some time had scouts out for a second-hand one that would meet our requirements, and very fortunately one of them had just located, at a plant near Springfield, a motor-driven centrifugal underwriters' unit that would handle our work perfectly, but at a somewhat lower efficiency than the one designed for our plant. Within twenty-four hours a trade was made for this unit and a truck sent to Springfield after it.

In the rear of the station was a place where the main supply line from the pond was not over five feet below the surface. Here a hole about 8 ft. by 12 ft. was excavated alongside the pipe, a concrete foundation run, an 8-in. tap made in the supply main and a line of 12-in. pipe laid to connect with the force-main in front of the station.

A small building nearby, about large enough to house a Ford car, was skidded over the excavation, the sides banked up, and we were ready for the pump.

This arrived just before the preparations were finished, and while the water department gang was setting it up and making the connections, the electricians arranged transformers and connected switchboard, so that on December 9 the unit was started, and continued without interruption for the remainder of the winter.

Had it been impossible to obtain an emergency electric unit, the writer, as a last resort, contemplated hooking up two 700 g.p.m. motor pumpers from the fire department to the same outdoor connections prepared for the centrifugal pump.

After the other motor-driven unit had at last arrived and been installed, this emergency outfit was moved to the basement of the station and set up permanently, giving us two 1 500 000 gal. electric units in new condition and two 1 500 000 gal. steam units badly crippled.

The water end of the Deane pump was then taken from the foundation, and it was found that in addition to the crack that we had been treat-

ing with asphalt, there was a larger one on the opposite side and absolutely inaccessible when the pump was on its base.

The writer determined to spend not over \$200 to put this pump in condition to serve as a standby for the motor-driven equipment. Fortunately both cracks were along plane surfaces rather than at the intersection of a vertical and horizontal surface as was the case with the Blake pump; and it was possible to plane down strips about four inches wide, centered on the cracks, tap for numerous $\frac{1}{4}$-in. boiler plate screws, and screw down a $\frac{3}{8}$-in. steel plate with rubber gasket, covering the entire crack. The planing left very thin metal along the line of the crack but as most of the screws were in at least $\frac{3}{8}$in. of metal the finished job was firm and strong and absolutely tight under 100 lb. test pressure.

The pump worked perfectly when started, and did all of the pumping for about two months last winter when we ran the steam plant to use up a surplus of coal that was on hand, when electric pump was started. The entire repair job cost less than \$100 exclusive of work of removing from foundation and lining up again, which was done as spare-time work by our own force.

The adventure, from start to finish, including the two electric units, emergency installation and subsequent changing of pump to permanent position, and emergency and permanent repairs to steam pump, cost a little less than \$8 500; about one-half the cost of one 1 500 000 gal. steam pump.

This was a case where the change from steam to electric drive was justified, inasmuch as it enabled us to meet the emergency successfully without any noticeable increase in operating costs.

If there is any worthwhile lesson to be gained from this experience, it is, that with a corrosive water there is a limit to the safe life of the water end castings and that this possibility of corrosive action should be provided for in the original design.

DANGERS TO THE SANITARY QUALITY OF PUBLIC WATER SUPPLIES.

BY E. SHERMAN CHASE.*

[*September 15, 1922.*]

The major dangers to the sanitary quality of public water supplies are, in general, well-known to engineers, sanitarians and water-works officials and the necessity for adequate protection against such dangers is thoroughly appreciated. On the other hand, many of the minor dangers are less well recognized and the extent to which precautionary measures should be taken to guard against some of these is still a matter regarding which opinions are not unanimous. The following paper has been prepared therefore with the view of stressing the lesser sanitary hazards, illustrating these hazards in most cases with accounts of outbreaks of water-borne disease for which they have been responsible.

For convenience and clearness the hazards will be discussed under three classes, namely — hazards to surface supplies, to ground water supplies and to supplies in distribution systems.

Hazards to Surface Water Supplies.

The direct discharge of sewage into bodies of water from which public water supplies are taken is, of course, the best recognized danger. Of late years, the almost universal adoption of purification of supplies taken from sources receiving direct and continuous sewage pollution has resulted in a marked reduction in the typhoid-fever death rate in those municipalities having such supplies. The effect of the purification of badly polluted supplies at Lawrence, Cincinnati, Philadelphia, Pittsburgh and many other cities, is well known.

This direct discharge of sewage into sources of water supply constitutes the greatest danger to public water supplies; but this fact is so well-known that there is no need of dwelling upon it at greater length.

Indirect Pollution. The danger from the indirect and less obvious sources of pollution, although relatively less serious than from direct contamination, is nevertheless very real; and examples of outbreaks of typhoid and other intestinal disorders due to indirect pollution are not lacking.

Very few watersheds are entirely free from human habitations. Wherever there are habitations there is also the possibility of typhoid or dysen-

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tery and the accompanying danger of the germs of these diseases reaching the watercourses draining the areas upon which the habitations are located. The disastrous epidemic at Plymouth, Pa. is well known.

Two examples of outbreaks of intestinal disease resulting from the infection of unpurified water supplies from relatively small and sparsely settled drainage areas have come under my own observation:

Washingtonville, a small village of about 600 inhabitants in eastern New York, obtains its water supply by impounding the waters of a small

Site of House in Which Typhoid Patient Lived Who was Original Source of Infection for Well-known Plymouth, Pa. Typhoid Epidemic.

stream in a 5 m. g. reservoir. The watershed tributary to the reservoir consists of about 3 sq. mi. of farm land upon which there were, at the time of which I speak, but 10 occupied houses with a total resident population of about 50, or 13 per sq. mi.

On February 12, 1918, there came a sudden thaw and heavy run-off in the brook which was followed by a considerable number of cases of acute dysentery in the village, most of the cases occurring between February 14 and 17. About 30 cases came to the attention of the local health authorities, but there were undoubtedly many more.

The sanitary conditions upon this watershed were not particularly bad, but the stream received run-off from highways, manured fields, barnyards, etc. One privy was located on the banks of a swiftly flowing brook but a short distance above the reservoir. A particularly significant fact is that one of the residents had been having intestinal trouble and diarrhea

during the early part of February, and had been working upon the construction of a small dam and ice-house on the main stream tributary to the supply.

A small but interesting outbreak of typhoid occurred in Westfield, New York, in the late summer of 1915. The water supply of Westfield is derived from a surface stream and at that time no purification was provided. The water-shed has an area of 23 sq. mi. and a population of about

PRIVY ON STONE BROOK INFECTING THE WATER SUPPLY OF LOWELL, MASS., AT THE TIME OF THE EPIDEMIC OF 1890.

27 per sq. mi. Opportunities for pollution are numerous from railroad tracks, highways, farms, privies, etc.

The outbreak consisted of about a dozen cases of typhoid in a population of 3 500; a relatively mild epidemic. The investigation narrowed down the probable cause to the public water supply, and later disclosed the fact that a single case of typhoid had occurred upon a farm 5 or 6 miles from the intake in a house a few hundred feet from the bank of the main stream. The privy was located on a rather steep slope leading to the stream. The farmer who had typhoid had been taken ill about two weeks before, going to bed. During this period he worked around the farm and during this same period there were heavy rains. The first case in the village occurred about one week after the farmer had taken to his bed and the others followed in rapid sucession.

These examples indicate how disease germs from a single case of illness may reach public water supplies. In the two cases cited, the indirect manner in which the germs reached the supplies and the dilution by heavy run-off evidently brought about considerable attenuation of the infection, otherwise outbreaks of more serious proportion would have undoubtedly occurred.

Manured Fields. A rather startling demonstration of pollution by drainage from manured fields occurred in the village of Cazenovia, N. Y. in the early part of 1918. The water supply of this village was at that time derived from a small upland reservoir, springs, wells and at times from Cazenovia Lake. None of the various sources could be considered above suspicion. During the winter of 1917-1918 the field adjacent to the reservoir was heavily fertilized with barnyard manure. Shortly afterwards there occurred a very sudden and heavy thaw which carried such quantities of manure and seepage from the manure into the reservoir that water in the village was dark mahogany in color and actually frothed when drawn from faucets in the houses. Fortunately, no known ill effects followed this occurrence due evidently to the decidedly objectionable character of the water preventing people using it for drinking.

Boating, Bathing and Fishing. The potential danger of contamination as the result of boating, bathing and fishing upon bodies of water serving as water supplies is, of course, well recognized, although actual examples of epidemics resulting from infection as the consequence of such practices are difficult to cite. This is to be expected owing to the usually transitory nature of such contamination. In the JOURNAL of this Association for September 1921, Mr. Goodnough in his paper upon " Boating and Fishing in Ponds and Reservoirs used as Sources of Water Supply "referred to the experience at Lake Saltonsall, Haverhill, Mass. This pond is an emergency source of water supply for the city but used very rarely. Fishing and trespassing upon the pond had formerly been forbidden but as the result of many and insistent demands for these privileges the pond was opened to the public. As a result, sanitary conditions around the pond became extremely objectionable and the privileges had to be withdrawn. Mr. Goodnough also referred to the 1913 outbreak of 500 cases of enteritis in Peabody, which was attributed to an infection of the water supply by fishermen, described in detail by Mr. Weston in the same issue of the JOURNAL.

Ice Cutting. The danger of contamination by men engaged in ice cutting upon water supply reservoirs and ponds is also a hazard, the ill effect of which it is difficult to prove by actual examples. In 1917 there occurred an outbreak of typhoid fever in the city of Hillsdale, Mich., which was attributed to an infection of the city water supply by a crew of men engaged in ice cutting upon the lake from which the supply was obtained.

Another instance of the probable infection of a public water supply by men engaged in ice cutting from a reservoir occurred at Sherburne, N. Y., in 1908. The water supply of this village is obtained from a 4 sq. mi. watershed of farm land and distributed from two reservoirs of about 12 m.g. and 20 m.g. capacity respectively. In March, 1908, there broke out in a population of about 1 000 some 10 cases of typhoid. An investigation disclosed the fact that at times during January and February a dozen men

or so had been cutting ice from the reservoirs and that during February there had been a thaw. Excreta were found upon the bank of one of the reservoirs, evidently deposited there by men engaged in ice cutting. Although other sources of contamination existed upon the watershed none was as near the point at which the water entered the main to the village nor were there any cases of typhoid upon the watershed. Whether any of the men cutting ice was a carrier or whether any was ill at the time of being at the reservoir was not determined. The coincidence of ice cutting, excreta upon the reservoir bank, and a thaw, indicates strongly, however, that infection of the supply was due to the ice cutters.

A Summer Cottage on a Pond in Massachusetts Used Unpurified Water as a Water Supply.

In addition to the danger of contamination by the men harvesting the ice, there is also the danger from the men removing the ice from the ice houses in summer. Ice cutting itself is frequently carried on under sanitary inspection but the removal of the ice is usually under no such supervision and the danger may therefore be greater.

Lumbering. Lumbering operations upon timbered watersheds is another hazard of relatively frequent occurrence, but one to which infection of water supply has seldom been traced.

There is one case to my knowledge where there was some evidence that lumbering operations on watershed was the cause of a small outbreak of typhoid although the evidence was inadequate to prove beyond question that this was a fact. This example which I have in mind oc-

curred at the New York State Hospital for Incipient Tuberculosis at Raybrook, N. Y.

The water supply of this institution is obtained from a small upland watershed of about one square mile in area. Originally, it was a wild, uninhabited mountainside with no habitations nor roads. In June, 1917, a lumber camp was established about a mile and a half above the intake, logging roads built and lumbering operations begun. Twenty-five or thirty employees were stationed at the camp and the privies for these men were located close to the brook tributary to the supply of the hospital. In September some six cases of typhoid developed among the 400 people at the hospital. No record of typhoid was found among the camp employees but some had left the camp before the investigation was made. While other causes may have accounted for the outbreak, it is evident that a very serious menace to the safety of the supply existed.

Labor Camps. Labor camps, unless most careful sanitary oversight is maintained, also constitute a menace to water supplies when located on watersheds. Two serious outbreaks of typhoid occurred some years ago in New York State which may have been due to infection by laborers in camps upon watersheds. The best known of these outbreaks is the Ithaca one.

The epidemic of typhoid in Ithaca in 1903 was described at length by Dr. Soper before this Association in 1904. During the first three months of 1903 there occurred among the 13 000 inhabitants and 3 000 students at Cornell University some 1 350 cases of typhoid and 82 deaths. At that time the city supply was furnished by a water company and was derived from two different streams, Six Mile Creek and Buttermilk Creek. The University had an independent supply of its own, but the students had access to the general city supply at boarding places and elsewhere. Upon the watersheds of all three streams were numerous opportunities for pollution. The evidence, however, indicated that the University supply was not responsible for any of the typhoid.

The exact source of the infection was not definitely fixed. On Six Mile Creek there was a gang of Italian laborers engaged in the construction of a new reservoir; and an infection of the stream by some unrecognized case of typhoid among these men was considered as a possible source of the epidemic. On the other hand, the watershed of the stream was 46 sq. mi. in area, with a resident population of over 2 000, and many sources of pollution existed. Furthermore, there had been another gang of laborers engaged on the construction of a culvert on the watershed, and it was found that one of these laborers had had typhoid while on the work. Excreta were found on the bank of the stream in the vicinity of the culvert.

On Buttermilk Creek also there were known to have occurred at least 6 cases of typhoid during the 12 months preceding the epidemic.

During the latter part of December, 1902, there occurred heavy rains and a thaw which evidently resulted in infectious material being washed

into the stream and being carried rapidly to the water-works intake. It also happened at about the same time that excessive pumping had been carried on for the few days preceding Christmas 1902, thus bringing infected water into the mains when there was less detention than usual in the reservoir.

While it is evidently impossible to state with any degree of positiveness that the typhoid case in the gang at work on the culvert was the original source of the infection, the circumstances are very significant.

RAILROAD IN CLOSE PROXIMITY TO WATER SUPPLY STREAM.
(Courtesy of Earl Devendorf.)

Another instance where a labor camp was considered as the very probable source of infection for a public water supply occurred in the case of the village of Peekskill, New York, in 1908, during the construction of the new Catskill aqueduct which crosses the watershed tributary to the Peekskill supply.

Highways and Railroads. The infection of water supplies by travelers upon highways and upon railroads is also a danger of which definite examples are impossible to prove. You will recall the severe outbreak of typhoid in Scranton, Penn. in 1906, at which time considerable emphasis was laid upon the probability of infection of one of the reservoirs by excreta discharged from passenger trains which paralleled the reservoir and tributary watercourse for some distance.

Shortly after this outbreak at Scranton the new water supply of Seattle, Wash., was begun and in order to prevent any similar infection very elaborate sanitary precautions were observed.

Cross Cuts in Reservoirs. A condition with respect to pollution and possible infection, in the case of the smaller lakes and large reservoirs, consists of nullification of the beneficial effects of storage by the rapid transportation of polluting material from relatively remote points to the immediate vicinity of intakes by currents set up by various causes. An example of such short circuiting is recounted by Mr. Diven, Secretary of the American Water Works Association, which occurred while he was superintendent of the Troy, N. Y., water works. Troy obtains its principal water supply from the Tomhannock reservoir, an impounding reservoir of 12 000 000 000 gal. capacity and one into which the tributary streams enter at such points as to give ample opportunity for storage under ordinary conditions. In the winter of 1918, when the reservoir was covered with ice, there occurred a heavy rain and thaw followed by an extremely heavy run-off. The waters from one of the streams tributary to the reservoir flowed over the surface of the ice and reached the vicinity of the intake in a very short time and turbid water was drawn from taps in the city, an unusual occurrence. Fortunately no outbreak of disease followed.

This instance illustrates the fact that it is impossible to predict that storage and sedimentation in a large reservoir will at all times be ample to insure the safety of the supply.

Another illustration of the fallibility of storage as a means of securing safe water is afforded by the experience of Auburn, N. Y. This city secures its water supply from Owasco Lake, one of the so-called finger lakes of central New York. This lake is approximately 10 mi. long and about 1 mi. wide with its axis extending in a general north and south direction. The water-works intake is located at the northern end of the lake and the principal inlet stream enters at the extreme southern end. About 4 mi. from the lake the village of Moravia is located upon the Owasco inlet, so that the distance from the village to the Auburn intake is about 14 mi. The High School at Moravia was provided with a sewer which discharged upon the bank of the inlet and at time of flood excretal matters were washed down stream.

In the fall of 1907 there occurred in Moravia and the vicinity some 20 cases of typhoid among whom were High School pupils. In the spring following the floods there were reported in Auburn 45 cases of typhoid and 12 deaths, the actual number of cases being undoubtedly greater than were reported. An investigation made by Mr. Ackerman, former superintendent of the water department, Prof. Whipple, and several other prominent engineers indicated clearly the responsibility of the Moravia High School sewer for this outbreak and an interesting court action was carried out to restrain the school authorities from continuing the use of the sewer at fault.

In the investigation, studies were made of the effect of wind upon lake currents in order to determine the time required for possible infection to travel from the southern end of the lake to the water-works intake. It

was found that wind would set up currents in the lake water in the same direction as the wind and with velocities equal to 1 to 3 per cent of the wind velocities. It was also found that conditions were frequently favorable to bring pollution and possible infection from Moravia to the water-works intake in 3 to 4 days, a period of storage inadequate to ensure the natural death of the typhoid organism.

A third instance of the manner in which lake currents carry infection occurred in the case of the village of Seneca Falls, N. Y., also deriving its water supply from one of the "finger" lakes, Cayuga Lake. This lake is about 37 mi. long and from 1 to 3 mi. wide, with a drainage area of about 797 sq. mi. (excluding water surface) and upon this area there is a population of 30 000, including the city of Ithaca at the extreme southern end of the lake. The outlet from the lake discharges to the north through the New York State Barge Canal. Just above the beginning of the outlet the Seneca River enters the lake. Ordinarily the flow of water is from the lake through the outlet, but a short distance down stream at Mud Lock, gates are located which so control the flow that water entering the lake from the Seneca River, instead of flowing out through the outlet, will back up into the lake.

The water-works intake is located at the northern end of the lake about mid-lake, but between the Seneca River and the intake there is a railroad embankment which in a way dams off the very northern end from the rest of the lake. There are however, two channels through the embankment which permit free interchange of water between the two parts of the lake.

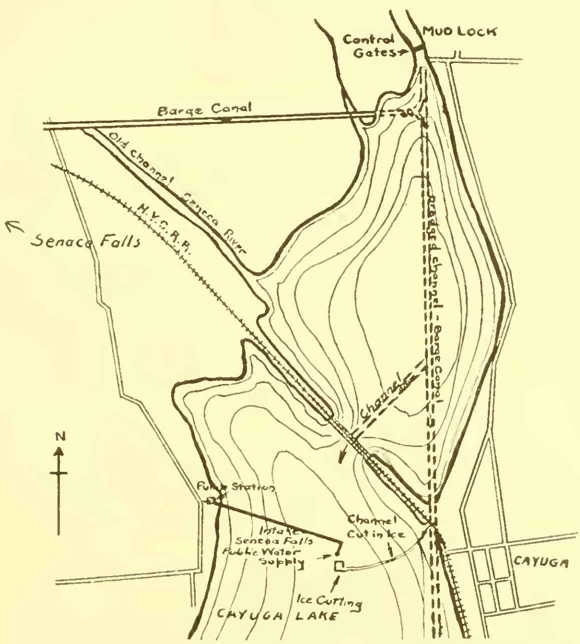
In the winter of early 1918 there occurred in Seneca Falls an outbreak of dysentery, although the water is filtered through pressure mechanical filters. It had been customary, however, to omit the use of alum during the winter months. At the time of the outbreak there occurred complaints of tastes and odors in the supply which were described as resembling "carbolic acid" or "iodoform."

The Seneca River receives sewage from the city of Geneva and from the villages of Waterloo and Seneca Falls. At Geneva there is a gas plant from which wastes enter the river. An investigation of conditions preceding the outbreak disclosed the fact that the gates at Mud Lock had been closed about the first of January, resulting in the backing up into the lake of the polluted waters from the Seneca River in such a way as to bring pollution to the vicinity of the water-works intake. Furthermore, at that particular time the water consumption in the village was unusually heavy and the rate of filtration was therefore very much greater than usual. Alum was being used only intermittently and the purification effected was evidently insufficient to remove the infection.

As an example of the same man being bitten twice by the same dog it is interesting to note that a similar outbreak occurred again in March 1920. During the latter part of March, there occurred a heavy run-off at

a time when the control gates at Mud Lock were closed. Turbid river water flowed into the lake in a southerly direction and a distinct change took place in the water received at the water-works intake and a slight turbidity was noticed in the water in the village, in spite of the filter plant.

Carriers on Watersheds. Although interconnected with other hazards, the possible existence of typhoid carriers upon watersheds is a factor worth considering. Examples of outbreaks of typhoid definitely traced to carriers upon watersheds are lacking, so far as I have been able to learn. There has come under my observation an instance where a carrier may have been a factor in the recurrence of small outbreaks of typhoid.



Sketch Map of Northern End of Cayuga Lake, N. Y.

The City of Mechanicville, New York, obtains its water supply from a small upland watershed about 4 sq. mi. in area upon which there is a resident population of about 200, or 50 per sq. mi. In 1918, at the time of an outbreak of typhoid in the city, a visit was made to every occupied house upon the watershed and upon inquiry it was found that of 20 houses, 10 gave history of typhoid in the family at some time or other, although at that particular time none was present.

The water is stored in small reservoirs and receives filtration through a rather crude and inefficient filter of the mechanical type but with no alum. It is easy to conceive the presence of a typhoid carrier upon one of the farms of the drainage area and the occasional discharge of typhoid germs upon the surface of the ground, which at times of rain were washed into

the streams tributary to the supply. If such were the case, the storage and the crude filter may have formed incomplete safeguards which prevented the outbreaks assuming more serious proportions.

Accidents to or Improper Operation of Purification Plants.

The installation of water purification works does not constitute an absolute safeguard against possible infection unless continuity of efficient operation is maintained. Accidents of one kind or another occasionally occur which result in unpurified water being delivered to the consumers.

One of the most striking accidents to a filter plant occurred to the Albany plant in 1913 when, as the result of the highest recorded flood in the Hudson, the filtration plant was inundated for a period of something over a day and raw Hudson River water pumped into the mains.

The filter plant was flooded early in the morning of March 28, and was out of service until about noon March 29, or about 30 hours. When it was apparent that the filter was to be flooded, warnings against the use of unboiled water were issued through the press but such warnings are futile and were evidently pretty generally disregarded. At the end of about two weeks cases of typhoid began to be reported and in all there occurred between 170 and 200 cases.

In the case of purification consisting of chlorination alone, danger exists from the possibility of equipment getting out of order and unchlorinated water being discharged into the mains. To minimize such a possibility it is advisable to provide duplicate equipment.

Various examples exist of outbreaks of water-borne disease resulting from the temporary interruption of operation of chlorination plants when such plants constituted the only method of purification. In Whitehall, N. Y., there occured in 1915 an outbreak of typhoid from an infection of the public water supply then derived unpurified from the Mettawee River. During the epidemic a chlorination plant was installed and this installation was followed by a cessation of the epidemic. Later, in 1918, there occured another but smaller outbreak and upon investigation it was found that chlorination had been interrupted on account of a breakdown in the chlorine apparatus, no duplicate being then provided.

Lockport, N. Y., taking its supply from the Niagara River with purification by chlorination, also showed increased typhoid when interruption of chlorination occurred. In May, 1916, the chlorination plant was out of service 12 hours, and three weeks later 14 or 15 cases of typhoid developed in the city. In neither of the two cases cited was the raw water highly infected and in all instances where chlorination was intermittent, only a comparatively few typhoid cases resulted; but increase in typhoid prevalence was preceded by failure to secure continuous chlorination, which would have been obviated had duplicate apparatus been provided.

Accidents to Intakes. In cases where water supplies are taken from large rivers or lakes receiving sewage pollution, but where the pollution extends in comparatively restricted threads of the stream or in limited portions of the lake, there occurs the hazard resulting from leaky intake pipes, should such intake pipes pass through the polluted portion of the body of water forming the source of supply.

Two instances of disaster resulting from leaky or broken intakes illustrate this danger.

Clayton, N. Y., a village of 2 000 population, derives its water supply from the St. Lawrence River. The intake pipe extends into the river some 600 ft. to a point where analyses indicated a good quality of water although there exists some danger of infection from boats and from the general pollution which reaches the river. One of the main sewers of the village discharged through a submerged outlet pipe laid three feet downstream from and for a distance of 75 ft. parallel to the intake pipe. In 1915 there occurred an outbreak of some 27 or more cases of typhoid which was attributed to an infection of the water supply. It was considered probable that leaks were present in the intake pipe which was under suction as it was directly connected to the pumps. Following this outbreak a chlorination plant was installed but so far as I know the sewer was not relocated.

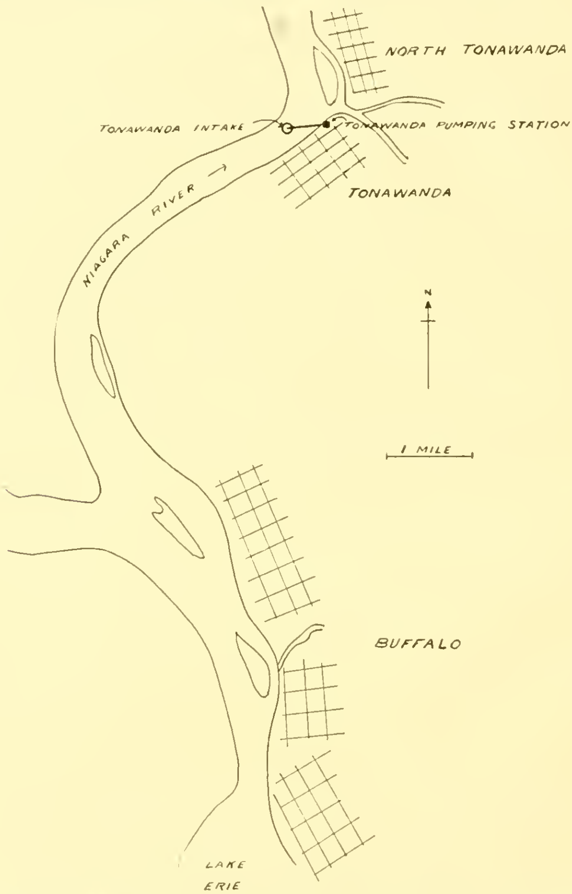
Another and rather striking example of serious results following an accident to an intake line is shown by the experience of the city of Tonawanda, N. Y., in 1919. This city obtains its water supply from the Niagara River, at that time with no purification, although located downstream from the city of Buffalo which discharges raw sewage into the river. The intake of the Tonawanda water works was located about 1 800 ft. from the American shore and in the thread of the stream which was relatively unpolluted, although by no means satisfactory for a public supply without treatment.

In the summer of 1919 dredging operations in the Niagara channel necessitated the lowering of the intake pipe of the Tonawanda water works a few feet and occasion was then taken to lay an entirely new and larger pipe of wooden stave construction and with a course somewhat different than the course of the old line. At one point the courses crossed and it was necessary to cut the old pipe somewhat nearer the American shore and consequently nearer the more grossly polluted waters. When the pipe was cut the water supply for Tonawanda was of course taken through the break rather than at the intake crib. The cutting of the pipe occurred some time during the last two weeks in June. Between July 5 and October 4 there occurred some 263 cases of typhoid in Tonawanda. The outbreak of typhoid was preceded by an outbreak of severe intestinal disorder.

Although previously advised to at least chlorinate the supply, it was not until August 11, with the epidemic in full swing, that chlorination

was resorted to. Following the adoption of chlorination the outbreak quickly subsided.

The new intake line was put into service on August 23 and on October 4 it was discovered that a leak due to a faulty joint was permitting grossly polluted water from near the shore line to enter the intake. After this was



SKETCH MAP OF NIAGARA RIVER AND TONAWANDA, N. Y., WATER SUPPLY INTAKE LOCATION.

corrected a second serious leak was discovered on October 9. During the existence of these leaks the water was being chlorinated and no increase in typhoid prevalence followed the admission of the very seriously contaminated water into the mains. The water was so badly polluted that when the pumps were cleaned basket loads of offal were removed.

Improper Operation of Purification Plants. An example of improper operation of a filter plant has already been cited in connection with the water supply of Seneca Falls, where, during the winter months, alum was used only intermittently.

Another example of the result of a failure to properly operate a filter plant is the case of an outbreak of thirteen cases of typhoid fever in the village of Massena Springs, N. Y., in the early part of 1917. The water supply of this village is derived from a power canal fed by the St. Lawrence River. The supply is contaminated as a result of the general pollution of the St. Lawrence River and at times from dredging operations above the intake. The supply is chlorinated and filtered through pressure filters. Just prior to the outbreak referred to, the filters had been out of service for about two months, and during the same period the chlorination plant was also out of commission.

Another instance of improper operation occurred in the case of Herkimer, N. Y. The regular supply of this municipality from well and an infiltration gallery became insufficient to furnish the required amount of water and recourse was had to a polluted canal water by pumping through a cross connection with a mill fire pump. An effort was made to chlorinate the supply thus obtained but due to difficulties in properly connecting up the chlorination apparatus there were several days when unchlorinated water entered the mains. After about two weeks from this pumping of unchlorinated water cases of typhoid began to occur in the city and eventually some 93 cases occurred.

Exhaustion of Water Purification Chemicals. A danger which must always be borne in mind in connection with water purification plants using any chemical is the possibility of supplies of the chemicals becoming exhausted before new supplies are available. This was a condition which was very acute during the war when freight movements and deliveries were very uncertain. Furthermore, this is a condition which is liable to be met with at any time of freight embargoes.

What may happen is illustrated by the experience of the city of Wheeling, W. Va., in the spring of 1920. Wheeling's water supply is derived from the sewage-laden Ohio river and at that time the only purification plant was chlorination apparatus. For three weeks during March and April, due to the failure of the city to secure deliveries of chlorine, the supply was unchlorinated. This condition of affairs was followed immediately by an outbreak of 28 cases of typhoid resulting in four deaths.

Poor Quality of Chemicals. A somewhat similar hazard to that referred to above is that of using chemicals deficient in strength. This is more liable to occur with hypochlorite of lime than with other chemicals used in water purification, due to its tendency to deteriorate on standing.

At Green Island, N. Y., an interesting outbreak of intestinal disease took place in December 1917, followed by typhoid in January 1918, resulting from a combination of conditions in which the poor quality of hypochlorite used for disinfection of the supply was attributed an important part.

The village of Green Island, with a population of about 5 000, is supplied with water obtained from an infiltration gallery located on a small

island in the Hudson River opposite the city of Troy. The water is filtered through gravity mechanical filters and disinfected with hypochlorite.

About the middle of December 1917, a sudden outbreak of dysentery broke out in the village, it being estimated that some 1 000 cases occurred. During the following January about 20 cases of typhoid developed.

It was found on investigation that in the middle of December an auxiliary intake from the Hudson River had been opened, allowing river water to enter the infiltration gallery. An attempt was made to meet this change in quality of raw water going to the filter plant by increasing the amount of hypo applied. At the time the river water was used the unsatisfactory physical character of the water was noted by the consumers, the water being discolored and with a bad odor. River water was again turned into the infiltration gallery on January 6 and again on February 5. On January 6 the superintendent of water came to the conclusion that the hyphochlorite being used was deficient in strength and he then took steps to secure a fresh supply of better quality.

Filter Plant By-Passes. Frequently by-passes are provided which permit the discharge of untreated water directly into the mains. For example, Geneva, N. Y., obtains its water supply from Seneca Lake about $2\frac{1}{2}$ mi. south of the point where the sewage of the city is discharged. Ordinarily the sewage flows out of the lake away from the intake; but under certain conditions of wind and lake currents it undoubtedly reaches the vicinity of the water-works intake. Purification by means of a slow sand filter plant has been provided but during the latter part of 1917 it became necessary to by-pass a small amount of raw water around the filters, on account of the inability of the filters to handle the entire water consumption of the city. Furthermore, when one of the filter units was out of service for cleaning, the amount of water by-passed became relatively large for several hours. This by-passing of raw water resulted in some 15 cases of typhoid occurring in the city which had become practically free from the disease after the installation of the filter plant.

Another example of filter by-passing occurred at Kingston, N. Y., in 1917. The water supply of Kingston is obtained from catchment areas on the easterly slopes of the Catskill mountains and subjected to purification by pressure mechanical filters. During August 1917, at the time of alterations to the filter plant, raw water was delivered to the city for a few days. Prior to the delivery of raw water public notice was given of the fact and the people were warned to boil water used for drinking. This warning was evidently heeded as little as such warnings usually are and some 18 cases of typhoid resulted.

Twenty years ago the raw water of both Geneva and Kingston would have been considered above the average insofar as sanitary quality is concerned. Nevertheless, both sources are subject to contamination and, evidently, to a moderate amount of infection.

A third example of filter plant by-passing with even more disastrous results than in the two cases just cited occurred in the city of Moline, Illinois, in 1918. The water supply of this city is taken from the Mississippi River and purified by rapid sand filters. Prior to the installation of the filter plant the typhoid death rate had been very high, 100, 144, and 151, during the three years immediately preceding the use of the filter plant. After the filters were in use the rate dropped to between 22 and 60 per 100 000 except for the year 1918 when the rate increased to 80 during the first three months.

One outbreak of typhoid occurred in the winter of 1917-1918 at a time when the filter plant was in poor condition, the sand layer in the filters having been reduced to but 10 in. or less, the rates of filtration were excessive, and the chlorination apparatus was out of order. The filter was then tuned up and put into proper operating condition but another outbreak occurred in July of 1918. Inquiry disclosed the fact that a by-pass around the filter had been open on two different days in June and at the same time one of the sedimentation basins was being cleaned so that the raw water had even less detention than usual.

Hazards to Ground Water Supplies. There is a popular opinion that water supplies taken from the ground are of better quality than those from surface sources, particularly supplies from what is termed "solid rock." There is some justification for the belief that ground waters are safer from a sanitary view point than unpurified surface supplies, due to the natural processes of purification to which ground waters have been subjected. On the other hand it is impossible to determine just what is taking place in the ground and it is also impossible to control the natural processes of purification as in the case of artificial methods.

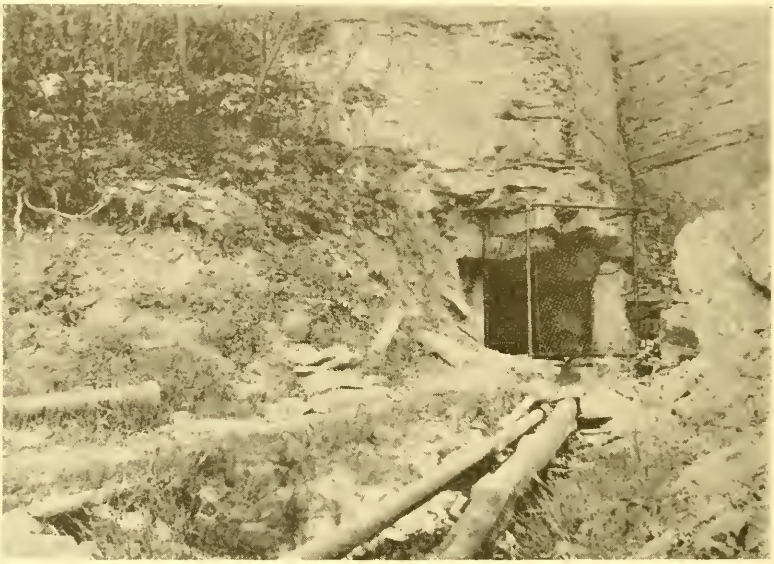
The safety of ground water supplies depends upon the remoteness of potential sources of contamination, the manner of development of the supplies, the character of material penetrated, direction of ground water flow with respect to the location of sources of pollution, adequacy of casing or curb to exclude surface waters, and freedom from chance pollution by polluted flood water.

General Pollution of Ground Waters. As a general thing it is inadvisable to sink or dig wells in a thickly populated district, due to the numerous opportunities for general pollution of the subsoil by leaky sewers, cesspools, privies, etc. It is not often that a public supply will be thus located although many private and semi-public wells will be located in the center of thickly-settled communities.

The city of Watervliet, N. Y., long suffering with one of the worst public water supplies in New York state, had, therefore, provided several public wells located at convenient points about the city. Most of these wells were located in the streets at the curb line and in many cases were not far distant from the street sewer. The wells were either driven or excavated to a comparatively shallow depth through fissured shale. Ana-

lytical examinations of the waters from these wells showed that practically every one was grossly contaminated. In one case a well was responsible for a localized outbreak of typhoid. Yet when the local board of health closed the majority of the wells there arose considerable popular outcry.

Channels in Strata. The character of the strata penetrated has an important bearing upon the quality of water obtained. In fine sand or homogeneous gravel the natural purification effected is reasonably sure of being complete. On the other hand, where wells are in limestone or



WATER SUPPLY SPRING FROM FISSURED LIMESTONE.
(Courtesy of Earl Devendorf.)

fissured rock direct drainage channels are likely to occur, through which practically unpurified surface water may enter the well. The historic case of Lausen, Switzerland, where a typhoid epidemic resulted from the infected waters of a brook flowing some distance through rock fissures to the public spring, is an example of the passage of infection through underground rock channels.

The accompanying picture shows a spring constituting part of the public water supply of a small municipality near Albany, N. Y. The spring consists of a small basin at the base of a steep escarpment of limestone into which water flows from a rock fissure of some size. Ordinarily the water is clear and colorless but following heavy rains it becomes somewhat turbid and organisms of the *B. coli* type are at times isolated from samples of the water, although there is no evidence of contamination by surface water in the immediate vicinity of the spring. The limestone formation from which the spring flows is fissured and full of channels. Furthermore, on the table land above the escarpment there are sink holes

from which there are no visible outlets. It seems probable therefore that at time of rain, surface water from this table land reaches the rock channels tributary to the spring.

Leakage along Casings. In the case of wells there is the possibility of leakage of polluted surface water down the outside of the casings of tubular wells or of leakage through holes or cracks in the curbs of dug wells. An example of leaky curb and pollution by flood waters followed by an outbreak of typhoid is the story of the 1915 typhoid epidemic at the Assembly of the Old Salem Chautauqua, Illinois.

The water supply of this camp ground was obtained from three wells, all exposed to local contamination and located on such low land as to be flooded at times of high water in the Sangamon River, which receives the sewage of Springfield, Ill., some 27 miles upstream. There had occurred in 1907 a flooding of the wells and an extensive outbreak of dysentery. Again in 1915 flooding of the wells during Chautauqua occurred and resulted in an outbreak of about 200 cases of typhoid with 13 deaths, the typhoid being preceded by a dysentery outbreak of at least 500 cases. The main well was surrounded by an embankment which was full of holes made by burrowing animals and the lining of the well was far from tight. Sufficient river water leaked into the well to give a distinct turbidity to the supply.

The attendance at the Chautauqua ranged from 500 to 3 000 daily thus giving opportunity for the exposure of a great many people to the infection. As this Chautauqua drew people from various parts of the state the effect of the epidemic was widespread.

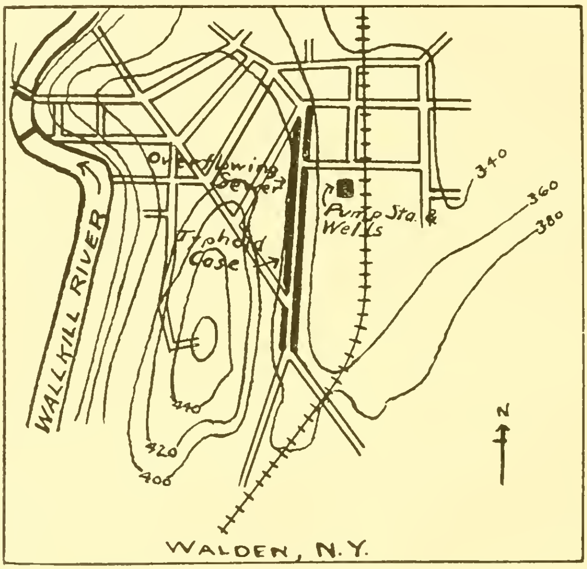
Proximity of Leaky Sewers. The location of sewers in the vicinity of sources of ground water supplies, also constitute a potentially serious menace to the safety of the supplies due to the danger of leakage from joints, or to overflow, whereby sewage may escape into the tributary ground water.

The village of Walden, N. Y., with a population of about 4 000, derived its public water supply from two sets of wells, one set being located outside the village limits and away from possible sources of pollution and the other set being located in the village and surrounded at greater or less distances by numerous houses.

The wells within the village are the ones with which we are concerned. These wells were driven wells with iron casings extending to depths of 80 to 100 feet through loam and shale rock. Analyses of the water from the wells indicated pollution of the ground water tributary to them, and. at times, active contamination by organisms of fecal origin.

In the latter part of 1913 there occurred an outbreak of about 50 cases of typhoid fever. An investigation indicated an infection of the public water supply as the probable cause of the epidemic. It appears that shortly before the outbreak there had been a heavy rainfall, at which time a sewer in a street about 200 ft. distant and at a higher elevation than the wells, had become clogged; and sewage from it had backed up through

manholes and vent pipes on house laterals, and had flowed over the surface and into the ground in the general direction of the wells. It was also found that just prior to the overflow of the sewer a woman who was convalescing with typhoid fever had moved into a house tributary to the sewer line and just above the point where the overflow occurred. At the time the overflow took place the woman was suffering from a relapse and was undoubtedly contributing typhoid germs to the sewage which flowed out towards the wells. Furthermore, just about the time of the overflow the pumping station for the wells in the village was being operated for longer



Sketch Map of Walden, N. Y., Showing Location of Water Supply Wells Infected by Overflowing Sewer.

periods than usual, due to certain construction work that was being carried on at the other pumping station, so that the draft upon the village wells was double the usual amount. The chain of evidence proves pretty conclusively that typhoid-laden sewage was drawn through rock channels into the wells, with the unfortunate sequel of a typhoid epidemic.

Mr. Dittoe of the Ohio Department of Health in a paper before this Association last year gives another interesting account of an infection of a ground water supply, which took place at Salem, Ohio, in the fall of 1920. At that time Salem with a population of about 10 000 had an epidemic of some 884 cases of typhoid with 27 deaths. The typhoid was preceded by two outbreaks of enteritis, in the second of which it was estimated that there were about 7 000 cases.

The water supply of Salem is derived from a series of driven wells pumped by air lift or deep well pump to receiving reservoirs and thence

to the distribution system. One set of wells is poorly located with respect to possible pollution from privies and abandoned cesspools in the vicinity. Water from one of the other sets of wells was delivered to the reservoir through a line of tile pipe laid in the street parallel to and below sanitary and storm sewers. The evidence showed clearly that the primary cause of the outbreak was sewage leaking into this tile pipe.

Connection with Polluted Surface Water. Occasionally there exists physical connection between a pure ground water supply and a polluted surface supply which under certain conditions results in contamination of the ground water supply. An example of such a connection which existed for many years without causing any trouble, and had been lost track of as city administrations changed, occurred in Schenectady, N. Y.

The water supply of Schenectady is obtained from three large dug wells located on a flat piece of land near the south bank of the Mohawk River. These wells are about 400 ft. from the river and about 40 ft. deep. Ordinarily the water level in the wells stands below that in the river but it is not probable that the supply is infiltered river water. The sanitary quality of the water is excellent and it had been considered one of the safest in the state of New York.

In March 1920 there occurred high water in the river and about the same time a slight turbidity was noticed in the city water, a supply which had been invariably clear and colorless. Shortly after the appearance of turbid water in the mains an outbreak of gastro-enteritis took place, followed by some 53 cases of typhoid, of which 3 were fatal.

Investigation disclosed the fact that there were two 24-in. suction pipes which originally extended through well No. 1, thence through two parallel pipe galleries to a manhole about 30 ft. north of the well, whence they continued underground to the river. The pipes had been removed from the galleries and the holes through the walls of the wells sealed with concrete. The bottoms of the galleries were not paved and consisted of porous gravel. The walls of the wells were of masonry with open joints. The pipes from the manhole to the river had not been removed. Upon inspection of this manhole it was found that only one of the pipes was sealed and that the other had presumably clear passage to the river. Furthermore, it was clear that the galleries had been flooded with river water and that this river water had entered the well through holes in the porous gravel constituting the bottom of the galleries and through the joints in the masonry wall of the well. As soon as the conditions were discovered the pipes to the river were sealed with cast-iron flanges with tight gaskets, two sections of the pipe between the manhole and the river were removed, and the four ends thus exposed sealed with cast-iron flanges and tight gaskets and the trench backfilled with impervious material.

One of the most amazing instances of gross pollution of a ground water supply and resultant epidemic occurred at Mankato, Minn., in 1908. The water supply of this city was obtained from four artesian wells which

when not being pumped gave a pressure of 10 to 12 lb. per sq. in. at the top of the casing. In time, corrosion of the iron casings resulted in leakage of well water when the wells were not being drawn upon by the pumps. Instead of repairing the casings an 18-in. by-pass was laid to a near-by city sewer into which the leakage could flow. Later another pipe was laid for flushing boiler house ashes into the adjacent Minnesota River and the overflow from the wells was carried into this new pipe and the old 18-in. pipe straightway forgotten.

At times the Minnesota River reached unusually high stages; and to prevent backing up of river water and sewage into cellars, a gate was installed in the sewer below the point of junction with the old 18-in. overflow pipe. A 5-in. centrifugal pump was installed above the gate to pump the sewage and storm water from the sewer.

Just prior to the epidemic of 1908, there had been a heavy rainfall, high water in the river and large flow in the sewer. The gate in the sewer was closed, the pump started but did not care for all the sewage, which backed around through the 18-in. overflow from the wells, and the water supply pumps accordingly discharged a mixture of sewage and well water to the city. The result was 4 000 to 5 000 cases of enteritis, 417 cases of typhoid and 35 deaths.

Distribution System Hazards.

Not only is it essential to deliver a pure and wholesome water to the distribution system but it is as important to make sure that no opportunity exists for contamination to reach the supply in the distribution system itself. From the time a supply of safe character enters the distribution system it should not be exposed to accidental or deliberate contamination in accessible reservoirs, nor to the introduction of impure water through cross connection between the water-works mains and industrial systems with supplies from polluted sources.

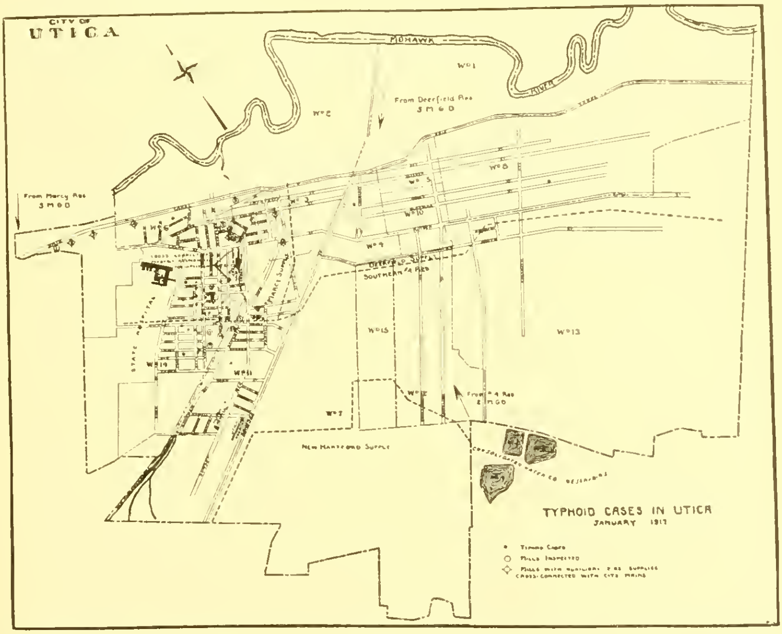
Cross Connection. Numerous instances are on record where typhoid outbreaks have resulted from polluted water entering the public distribution system through cross connections with industrial or fire protection supplies. The Lowell outbreak of 1903 is well known.

Another example of infection through cross connections occurred at Utica, N. Y., in January and February of 1917. At this time there took place a sudden and restricted outbreak of typhoid in a certain section of the city. Except for the water supply there was no other source of infection in common, and yet outside a rather limited district there were practically no cases of typhoid.

The water supply of Utica is derived from two sources, a hard upland supply from the south and a soft creek water from the north. All water to the city was chlorinated and for many years the water company had maintained unusually careful oversight relative to sanitary conditions upon the watersheds. There was no evidence to show any general infection of

the supply, in fact the evidence was pretty conclusive that there was no such general infection.

Inquiry disclosed the fact that a certain woolen mill which had not been operated for some years was being put into service again, and, in connection with the general overhauling which was given to it preparatory to operation, the fire system had been more or less changed and improved. This fire system with mill hydrants and sprinklers was connected with the city mains at two different points on two different streets and separated therefrom by single check valves. Ordinarily the pressure was from the city supply but a fire pump was provided for pumping an emergency supply into the fire system from a badly polluted stream which flowed through the mill property. The check valves were supposed to protect the city supply from any creek water which might be pumped into the fire system.



Sketch Map of Utica, N. Y., Showing Typhoid Outbreak from Cross-Connection with Mill Fire Supply.

About the middle of November, 1916, tests were made with the fire pump, at which time the pressure on the mill fire system reached about 135 lb. per sq. in., whereas the city pressure was only 90 lb. per sq. in. During the latter part of November following this test, a great many cases of enteritis occurred in that part of the city adjacent to the mill. Circumstantial evidence pointed to leakage through the check valves bringing local contamination into the city mains from the mill supply. No special test was made on the fire pump immediately preceding the outbreak of typhoid in January and February following, but the relative location of the check

valves was such that with the checks not quite closed, the pipes of the mill system would tend to become part of the distribution system of the city. Just what specific combination of circumstances was responsible for the infection was never discovered; but the mass of evidence was so strong against the fire system that the city passed an ordinance requiring the physical separation of polluted auxiliary supplies from the city supply. In the practice double check valves were allowed if properly installed for inspection and test.

Another instance of infection through a cross connection took place some years ago in Rochester, N. Y. A lift bridge over a canal was so constructed as to be operated by either one of two supplies of water. One of the supplies was the regular supply of the city used for domestic and other purposes while the other supply was an entirely separate supply used only for fire protection and obtained by pumping directly from the polluted Genesee River. The two systems were never intended to be turned into the operating house for the bridge at the same time, and the street gate on the one system was supposed to be shut when not in use but as additional precaution check valves on each system were installed.

Between inspections a zealous but ignorant canal employee obtained a gate wrench, closed the open street gates and then removed the checks or flaps from the check valves, after which he opened both street gates. The result was that contaminated river water entered the domestic supply and an outbreak of typhoid followed.

It would be possible to recount case after case of similar infection through cross connections as those cited above. Double check valves in accessible manholes with provision for testing and inspection have been urged as a means for providing the fire protection desired by the Underwriters Association and at the same time securing safety for the public supply. Such installations are unquestionably an advance over the haphazard single check valve installation but there is no assurance that deliberate tampering with such double checks will not occur nor that both checks will not leak at the same time. Double checks reduce but do not remove the hazard.

Emergency Supplies. The use of emergency or auxiliary supplies from polluted sources is a practice fraught with unpleasant possibilities. Emergency chlorination if properly applied from the beginning of the use of such a supply minimizes somewhat the danger but it is essential that chlorination be started as soon as the emergency supply is used and that continuous application of adequate amounts of chlorine be maintained.

The case of Herkimer already cited is an example of the use of an emergency supply with which proper chlorination was not obtained.

Watervliet, N. Y., originally secured its supply from the Mohawk River which was bad enough when used without purification; but occasionally it became necessary to supplement the Mohawk supply from the Hudson River with intakes located below the sewers of Watervliet itself, to say

nothing of the general and very considerable pollution of the river from many other municipalities. Invariably the use of the Hudson was followed by an outbreak of typhoid even though the city had excessive typhoid practically all the time. This was a case of going from the frying pan into the fire. Fortunately the city now has an upland supply filtered and chlorinated and typhoid has been practically eliminated.

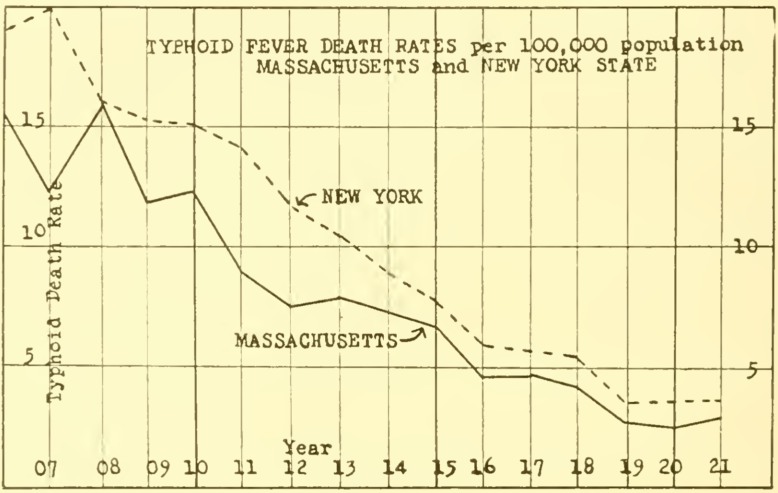
Dual Water Systems. Dual water supply systems, one of safe and wholesome quality for drinking and general household use, and the other impure and for fire protection and industrial use, have been suggested. In the case of individual mills such dual supplies are actually in use in many instances. This is a practice not without danger due to the impossibility of completely preventing the use of impure water for drinking when readily accessible.

I recall an instance on an investigation of a small outbreak of typhoid in an industrial establishment which was supplied with safe city water and also with an industrial supply from the polluted Hudson River. Inquiry disclosed that the industrial supply was frequently used for drinking by the employees. In fact, while walking through the factory, I noticed one of the men drinking the industrial supply from a hose connected with one of the pieces of equipment.

Whenever an unsafe supply is accessible, there will always be some careless or ignorant people who will use it for drinking. Unless such industrial supplies can be made absolutely inaccessible, the safest course is to chlorinate.

Accessibility of Distribution Reservoir. There is one more hazard connected with distribution systems which is not unknown here in Massachusetts and while probably not one to grow extremely alarmed about is one which constitutes a real menace to some of our supplies. I refer to the ready accessibility of distribution reservoirs with pleasant walks and drives around them in very close proximity to the water's edge and with nothing to prevent contamination of the waters except a few absentee policemen and an occasional sign. In these days of tourists from every part of the country, one never knows when some typhoid carrier from a section less fortunate than Massachusetts in the matter of freedom from typhoid will unknowingly contaminate and infect some of our reservoirs located so conveniently alongside main-travelled highways. It is a remote contingency, perhaps, but the unexpected always happens, and in the little stories of typhoid outbreaks which I have given the element of chance will be noted and the eventual combination of conditions which so frequently resulted in disaster. It may be that such an infection of an open distribution reservoir would occur not oftener than once in a hundred years but when that one time will take place no one can predict; it may be next year or 2022, but the danger is there and there is no assurance that infection will not occur to-morrow.

Miscellaneous Dangers. In addition to the hazards previously illustrated in more or less detail, there are those which may arise from casual visitors, such as picnickers and hunters, to watersheds, streams and reservoirs or from summer cottages upon the shores of lakes or ponds used as water supply. Mains occasionally break, which necessitates the by-passing of filters. Filters and chlorination plants are frequently housed in combustible buildings. Infection of mains under repairs by sewage leaching into water-pipe trenches or of standpipes and distribution reservoirs by



men cleaning them or making repairs are not impossible contingencies. In the case of supplies from large lakes infection may be brought about by excreta discharged from boats passing in the vicinity of intakes.

The typhoid death rate in this country has been steadily declining for the past 20 years due largely to improved methods in the protection of our water supplies. Outbreaks of water-borne disease are becoming less and less frequent but it must be remembered that eternal vigilance is the price for continued safety of our supplies. No hazard, however slight, can be overlooked without eventual consequences in the form of water-borne outbreaks of disease.

LIST OF CERTAIN OUTBREAKS OF WATER-BORNE DISEASE.

GIVING PLACE, CAUSE OF OUTBREAKS AND REFERENCES.

(For additional references see page 369 of "Typhoid Fever" by G. C. Whipple.)

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Discussion.

Mr. Robert Spur Weston.* I wish to express my appreciation of this excellent compilation of data. It will be useful to all sanitary engineers in their work.

I would like to add a brief account of an epidemic which occurred in the course of our practice in the Town of Woodland, Maine, situated on the St. Croix River which is just across from New Brunswick. The river which flows by the town has a sparsely populated drainage area and a mean flow of several hundred second feet. The water of this river was so highly colored that it was distrusted by the inhabitants of Woodland who resorted to well water with the result that during the summer there were some fifty cases of typhoid fever and eight deaths.

All of the wells were sunk in the granite, one of them to a depth of 180 ft. The surface of the earth in that region has been pretty well scoured by glaciers and the soil overlying the rock consists of boulder clay or till which varies in depth from 4 to 25 ft. This layer was too thin to protect the wells from contamination by drainage from cesspools sunk in the soil, many of them to the rock. Pollution probably followed the fissures in the rock to certain of the wells. Plans have been made to purify the river water by coagulation and filtration, and to do away with the wells as sources of supply.

Mr. Frederic I. Winslow.† (*by letter.*) The remarkably comprehensive and detailed paper by Mr. Chase emphasizes the number of dangers lurking in the water supply. One hesitates to think that there may be any more risks than above related, but one was called to my attention a while ago which is worthy of record, that it may be avoided hereafter.

The main supply of a fairly large town was drawn through a suction main laid at the bottom of a pond for a considerable length. This pipe was so light that if it were emptied it would float to the surface, and did this on two occasions, and for quite a long time the town innocently drank water which was mixed with the pond supply, which was polluted, mainly by street wash and general surface drainage. No marked harm came from this and the pipe was finally repaired, but the State Board of Health required that the water should be chlorinated, chiefly from fear of a recurrence of the previous experience. There was also a fear lest some of the town supply being drawn from wells, might suffer pollution.

After a year or so the chlorination injection required repair, so the apparatus was removed and sent away for repair. A prompt return of the apparatus was promised, but it was several weeks before the chlorination was again in operation. If, during this time, the suction main had again suffered mishap, the result might have been serious, but in any event, and indeed in all such cases, some method should be provided for temporary

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† Division Engineer, Metropolitan District Commission.

chlorination or some other method of effective treatment. Such a method must of course be sufficiently simple to permit of easy operation by the force employed on such work.

Mr. W. C. Hawley.* While of course not a source of infection, there is another difficulty which is facing those who operate purification plants taking water from our large streams upon which there are industrial plants, and that is the dumping of oil into our rivers. We have been up against that proposition on the lower part of the Allegheny River for several years past. There is a company there which has been using oil for fuel. When the oil tank is nearly empty, the residue which cannot be put through the burner, is dumped into a sump, and the first heavy rain flushes the oil out of the sump and into the river. I have seen that black, thick, heavy oil on the surface of the river covering an area of an acre or two acres in extent. I understand that some of this oil got into the sedimentation basin of the filter plant of the City of Pittsburgh, and that one filter bed was badly clogged with it. We got some of the oil into one of our sedimentation basins, but it was skimmed off in time to avoid trouble.

* Manager and Chief Engineer, Pennsylvania Water Co.

SOME EXPERIENCE IN METER SETTING AND MAINTENANCE.

BY JAMES A. MC MURRY.*

[*September, 1922.*]

At the Annual Meeting of the Association held in Boston in 1914 a paper was read, "Metering an Old City," n which were set forth some of the methods used, some of the difficulties encountered in the progress of the work and some information that it was possible to prepare from the limited data at hand concerning the finances of the department, and consumption.

It might be well to state that in 1908 when the Meter Act went into effect, the City of Boston had 5 thousand metered and 90 thousand unmetered services and that under the Act it was necessary to meter annually five per cent., or about 45 hundred of the old services and all of the new services installed.

It might also be well to add that there was very little information available on this subject and that public opinion was quite opposed to metering, and even some officials were afraid that the department would suffer through increased expenses and reduced income. Of course, income and consumption are two very important factors in every water department. Facts accumulated year after year force one to the conclusion that a metered city will not only keep the consumption within reasonable limits but will also receive sufficient income to meet department expenses.

Water takers are getting satisfactory bills (and in thousands of cases bills lower than under the annual rate plan) and the department is receiving more than sufficient to pay its bills, with quite a large surplus.

When the work was begun the practice of metering the larger buildings was continued for two years until 1911 when the Public Works Department was created. Then the district metering plan was adopted. Only in this way was it possible to prosecute the work successfully and quickly. Again it was necessary to arrest adverse public opinion by metering every house in the district, every taker being treated alike and therefore there was no further ground for the charge of favoritism. The district plan offered an excellent opportunity to study income and consumption of pre-meter days with subsequent results and to determine the per capita in the several classes of takers and the unaccounted-for waste.

In passing let me say that inside waste is not confined to the poorer buildings and the so-called poorer districts but it is found in all districts

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and in all classes of houses. The following figures tell briefly but quite fully the affect of meters on the consumption in Boston.

In 1908 the daily consumption was 98 300 000 gal. and the per capita 158 gal. In 1916 when the city was a little over 50 per cent. metered the daily consumption was 80 388 000 gal. and the per capita 105 gal. a decrease of 18 000 000 a day between 1908 and 1916. In 1921 the daily consumption was 85 609 000 a day, a per capita of 112 gal., a difference of 13 000 000 between 1908 and 1921.

The city is now 70 per cent. metered and 1922 indications point to a still further reduction. With respect to income, it has been so large that it was necessary to amend the statutes to permit the use of it in other departments. In 1908 the city had in use 5 000 meters varying in size from $\frac{5}{8}$-in. to 6-in. In 1921 there were in use 70 000 meters from $\frac{5}{8}$-in. to 12-in., — disk, rotary, compound and detector types, 60 000 of the $\frac{5}{8}$-in. size. Meters are installed inside generally, either on the wall or in ground boxes; but occasionally it is necessary to establish meters in outside boxes (concrete). These are sufficiently large to permit a man to enter. The last severely cold winter has convinced a good many that the small outside meter box is not serviceable in this climate.

By-passes are being eliminated as fast as can be done. It was the custom to install meters on by-passes or to by-pass meters at large plants.

In 1917 a government plant was served by a 16-in and a 10-in, with a 6-in. meter on a by-pass on the 16-in., and a 4-in. meter on a by-pass on the 10-in. Reports were being made regularly that these meters were out of order. It did not seem possible for them to get out of order so frequently and it occured to me that the main-line gates might have been opened from time to time. An examination proved this to be a fact. A 12-in. meter was placed in the 16-in. line and a 10-in. in the 10-in. line. The by-passes were removed, in spite of the appeals of the Government's representatives. They were convinced that the department could make changes easily and without any inconvenience to them. The quarterly bill was increased from $15 000 to $30 000.

It ought to be added that no attempt was made to steal the water at this plant.

At another plant there was a by-pass around one of the meters and accidentally a gate was opened and very little water passed through the meter. The by-pass was immediately removed.

Services regulate the sizes of the meters and from observation, it would seem that either the applicants wrongly state their demands or the departments are too generous. Personal examination of premises and a perusal of records indicate very clearly in many cases that smaller pipes and smaller meters would be sufficient. Therefore, more care should be used in determining the size of service pipes.

With 70 000 meters installed, meter maintenance is now quite a leading problem in the meter service. The large number of makes and

types make for a multitude of repair parts and consequently much time and attention is required of the repair man. All the makes of meters seem to meet the requirements of the new specifications but they differ very much in many respects. It may be necessary for a committee to design in every detail meters that would meet the needs of all water departments.

It is a practice of the Boston department to test each meter, new and repaired. I think that we are all agreed that repaired meters must be tested separately. Some may question the testing of new meters separately and would recommend the string test for new meters. Because it was necessary to change clocks on 3 000 meters of a certain make and hundreds of gears on another make and to make repairs and repack spindles on thousands of still another make, we were compelled to continue the practice of testing each meter separately for our own protection. Large meters are tested in the field.

Five plumbers with a team under the direction of a foreman install all the new meters. Six men and five vehicles changed and reset all the old meters. Twelve thousand meters were tested last year and sixty-two hundred meters were changed.

In conclusion, I think that you will all agree that meters have done a great service for the City of Boston in reducing the daily consumption from 98 000 000 a day in 1908 to 85 000 000 a day in 1921; with the income not reduced; with the people satisfied that water by meter rates is good for all.

SERVICE PIPES AND PLUMBING APPLIANCES: SOME EXPERIENCES, EXPERIMENTS AND RECOMMENDATIONS.

BY DAVID A. HEFFERNAN.*

When I was asked to prepare a paper to be read before this convention I agreed, for the reason that I had several things in mind that I believed should be brought before my fellow-members. I had in mind at the time the quality of the water with which Milton and other cities and towns of suburban Boston were being supplied by the Metropolitan system and the apparent indifference of the State Board of Health to that quality.

Later, as I started to prepare it, two other matters came to mind that I felt should be mentioned, which, so far as I can see, are so palpably at variance with proper water-works operation that I could not resist the temptation to speak of them at this time. They are:

Cheap plumbing appliances and their direct result on water consumption.

Pressure boilers.

I will, therefore, ask your kind indulgence if I do not appear to confine myself precisely to the subject, and for trying to include in this paper so many topics, one of which might require a long discussion.

In 1912 Milton began to use exclusively, for its services, genuine black wrought-iron pipe lined carefully with Rosendale cement in our own shop. Our couplings were lined with lead. The corporation tail piece was made into a lead gooseneck by means of a cup joint and the same method used for connecting with the service pipe. A T. H. S. & W. cock was used at the curb line and a L. H. S. & W. cock in the cellar. All fittings other than the lead-lined couplings were of brass. About two years ago complaints began to come in about poor pressure. Inspections revealed the results of violent galvanic action, which had caused the eating away of the pipe at the threads inside the brass fitting, almost completely filling the latter. Of course it has been known for a long time that two different metals or two like metals of different composition, immersed in water, incite and are the victims of galvanic action to varying degrees, according to the metallic composition and the impurity of the water.

However, I admit that its danger had not been forcibly brought before me until then. Immediately we began to work to overcome the trouble, by using, in the service, material on which the effect of the water would not be so disastrous. Our final result is to line all fittings and stops with lead

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so that no water comes in contact with any two metals other than lead and brass, or lead and iron. We have been using this type of service in our installations for two years past and are gradually replacing the brass fittings in our old ones with lead-lined malleable iron.

Other superintendents supplying their districts with water from sources other than the Metropolitan may have a different problem. In my opinion, the great majority of superintendents know too little of the quality of their water. Some, who have private supplies, are careful that their analyses should show that it is fit to drink; but have they studied these analyses with a view to the action of the water on the pipe material? And have they tried to correct any fault it may have, or use the pipe material least affected, or both? If not, I am afraid that they will have their hands full when their services begin to fill.

Then there are some who, simply because their water is analyzed by the State Board of Health, think that it must be all right and let it go at that. The majority do not attach sufficient importance to the results of these analyses.

A short time ago, in line with my investigating, I ran across an interesting case. A residence in Chestnut Hill was plumbed, in certain parts, with copper pipe in September, 1920. By March of the following year matters had got so bad that the owner of the house had the plumber who made the installations have several samples of the water analyzed. It seems that notice of the water was taken when bath sponges turned green. The analyses disclosed that the copper content ran up as high as 1.85 parts per million. Correspondence, examinations and analyses passed back and forth for a couple of months with suspicion gradually pointing to electrolysis. The telephone and Edison companies were asked to make some other arrangements with respect to the grounds on water pipes. Later, representatives of these two companies coöperated to the extent of changing their groundings to a point back of the meter.

Mr. M. V. Croker, Superintendent of Pumping Station at Newton, was consulted. His contention was that the aggravation of electrolysis in, and the resulting damage to, service pipes could be laid to the telephone ground, street railway stray currents, and the Edison ground, mentioned in the order of their relative importance, — the first being the worst offender, especially in instances of so-called divided ringing. He had constructed an insulator which was to be installed in the service pipe on the house side of the meter, which would prevent foreign currents passing that point. After installing this insulator he made tests as follows:

September 22, 1921.

Drop across telephone lead covered underground cable and house piping whether nipple is in circuit or not

$$\text{Volts } \frac{100}{1000} - \frac{140}{1000}$$

September 22, 1921.
Readings taken from rear of building to service end outside of nipple
Volts 0 - 70
Taken inside of nipple
Volts 0

September 22, 1921
Readings taken from end to end of nipple
Voltage varied from 15/1000 to 115/1000
Amps varied from 1/20 1/10

September 22, 1921.
Readings taken from service to house piping with nipple disconnected
Volts 15/1000 to 115/1000
Amps 1/20 to 1/10
Difference in reading shows 0 volts drop in nipple.

Respectfully,
M. V. Croker.

Readings taken October 5, 1921.

From rear of house to front corner of house where insulating section is located.

Outside of nipple voltage – varied from 0/1000 to plus 150/1000. Ave. 75/1000 volts approximately.

Inside of nipple – none.

Here is Mr. Croker's description of his device:

"The insulating device consists of exterior of non-corrosive metal in two sections. Upper and lower castings are insulated from each other through the medium of fibre at the flange and at the bolts. The interior consists of a tube of glazed porcelain through which the water passes, the porcelain being made water tight on each end by leather washers or any other suitable material. A vent hole at top and bottom of casting allows dry air circulation between porcelain and exterior metal and also provides a means of determining if porcelain is sealed tight on end gaskets. The purpose of this insulating device is to offset the abnormal corrosion and encrustation of house plumbing, due to the electrical grounding on service pipes of telephone, lighting, street railway leakages, etc.

"The supposition that the water service line to the street affords the best possible ground is decidedly at variance with facts when the premises contain a hot water boiler or steam boiler with direct connection as a method of supplying heat. The tendency is for the current to flow through house piping to the ground through these fixtures or laundry equipment or any object that has a large metal area next to mother earth or concrete. This applies in a great measure to the degree of conductivity of the piping, to wit, copper, brass, etc. This insulation is placed on the water service on the riser immediately inside the cellar wall, providing ample room, however, on the street side of nipple for the groundings already referred to, thus leaving the expensive house piping free from electrolytic action.

"The model shown here under test on the Gamewell Fire Alarm test table with Newton water, a ground water, stood a voltage of 3 000 before showing signs of electrical breakdown under 550 volts A. C. and 550 volts D. C. the showing on the end of insulation being twenty-one thousandths of volt (.021). It has been determined by removing water meters and testing with A. C. and D. C. meters that practically 75 per cent. of all services investigated to date show reading of electrical current."

I have talked with Mr. Croker, and although I have not installed his device, its success at Chestnut Hill and the logic of the thing appealed to me. At any rate, the readings taken in the case mentioned show the introduction of foreign currents into service pipes.

The perfect water must have three qualities:

1. It must be palatable.
2. It should not vigorously attack the carrying medium and fixtures.
3. Free from disease-breeding bacteria.

Cost is a minor consideration.

The joint committee made up of the Metropolitan Water and Sewerage Board and the State Board of Health states that the common practice in the construction of reservoirs is to strip the land of soil where practicable, thus preventing to a degree the growth of microscopic organisms. But as time goes on the growths may reach a point where filtration becomes necessary. As I understand it, about $2 000 000 was spent soil-stripping the Clinton storage basin, and it will not be long before this water must be filtered. *Algæ* is responsible for the odor and taste of the water, which is most noticeable in the spring. Later in the season, during dry spells, when the water level in the Wachusett Reservoir lowers, the authorities call upon the Cochituate for short periods to supplement the main supply. The water is, by itself, practically undrinkable, even to those whose tastes are not fastidious. However, with dilution with other waters, it is not quite so bad as it would be alone. I feel that it is not right to force this water on us. The cost of filtering would not be excessive and I incline very strongly to the belief that this should be done before the legislature goes ahead with the extensive Swift and Ware River projects.

Increase in Consumption.

The average daily consumption of the Metropolitan District for 1920 was 127 265 000 or 105.5 gal. per capita. In 1894, just before the district was established, the amount used was 89 gal. per capita per day. The following year, with the birth of the district, the consumption rose rapidly until 1904 when the more liberal use of meters was begun. The consumption remained high for several years, reaching 128.4 gal. in 1908 when 22 per cent of the services were metered, but the next year, following legislation which required the use of meters on all services, the general introduction of meters throughout the district proceeded rapidly until the year 1915 when 67 per cent. of the services were metered and the per capita consumption dropped to 68 gal. daily, this being slightly less than the 1894 figures.

This great and rapid reduction in the consumption by means of general application of meters appeared to solve the problem of waste prevention, but,following the comparatively small use of water in 1915, due to a combination of causes all operating to produce a minimum use of water, the consumption began to increase, and in 1920 had risen to 105.5, notwithstanding the fact that the percentage of metered services had increased from 67 to 75.

These figures, which are taken from the report of the committee mentioned show a general rise in the per capita consumption, following the creation of the district and a general reduction following the introduction of meters, which continued until about two-thirds of the services had been metered, when the consumption again began to rise, even though, remember, the percentage of metered services was increasing.

Defective Plumbing Appliances.

Now, the fact is, in my opinion, that the variance in consumption at the time of metering is due to the latter-day installation of faulty plumbing fixtures, and as long as these fixtures are permitted to be used, I cannot see any chance to reduce the present consumption. The only way out is to begin State control of all plumbing fixtures. If this is done, I look to see the consumption drop to 80 gal. in place of the present 105.

The present day policy of the average plumber seems to be to install fixtures that will deliver all the water possible, with no regard for the ignorant consumer who has to pay the water bills. By this I mean that fixtures are installed by plumbers who do not consider the fact that a meter is on the service and that all the water passing through the meter must be paid for, whether used or wasted.

I believe that the most wasteful plumbing device being installed today is the low-down tank (and it is low-down in more than one sense) with cheap fixtures.

We have made a practice in our department, when a customer complained of a large bill, of sending an inspector to visit the house and make an inspection of the fixtures. The excess amount of water used has been traced in 95 per cent. of the cases to leaky ball-cocks or defective valves in the closet tanks. Very often an inspector can tell of a leak that has been repaired by the old water line in the tank, thus confuting the argument of the consumer that they " could not understand why they had such a large bill as there had been no leaks, they had been careful as usual of the water, etc."

The rubber ball valve installation is a very common one among unreliable plumbers who cater to a cheap class of trade and among the altogether-too-common builders for speculation. The valve may work properly for a short time but soon becomes distorted and lies on the seat in a different position, causing seepage and finally leakage.

Another item along this line is this: the capacity of automatic syphon tanks is about seven gallons. Most all bowls require at the most three gallons to properly flush them. Furthermore, most tanks are permitted to fill to full or three-quarter capacity. This is an unnecessary waste of water. If three gallons will flush adequately, why use six or seven? I estimate that at least 50 per cent. of the water supplied to these tanks is wasted through improper tank fittings.

The amount of money being invested annually in plumbing supplies and fixtures is increasing rapidly and even now reaches millions of dollars. The regulation of plumbing has not kept pace with the increase in fixtures, so that, at present, we have on the market certain appliances which are worse than useless; they are a needless expense.

Hot Water Boilers.

Several years ago with the scramble for cheap plumbing some one conceived the idea that if a hot water boiler could be made to withstand ordinary street pressure, that boiler might be connected under direct pressure to the supply pipes, eliminating considerable piping and the cost of a tank on an upper floor. At the same time no inconsiderable amount of space was saved. Now, every cheap job of plumbing includes a pressure boiler, usually galvanized iron, frequently built into the wall in some almost inaccessible position.

Several problems have presented themselves as a result of the installation of pressure boilers. A relief valve must be provided, and a vacuum valve. With the present quality of the water how can we prevent the action on these valves which prevents their proper operation? The law in most municipalities insists on the use of these two valves. Theoretically and practically, they are necessary, but when called upon to do their duty after corrosion has had its day, theoretical action is all the valves have. More than half the time they stick or leak.

The extensively used automatic devices for heating water and the faulty manner in which they are connected should be controlled by law. Galvanized boilers are being used with brass connections, ½-in. galvanized pipe is used for the supply, often coupled with brass fittings. We know what a connection of brass to iron will do in most waters and how quickly ½-in. galvanized pipe will fill with rust.

I want to tell of a case of my experience a short time ago. In answer to a telephone call my night man visited a house where an 18 gal. Kompack heater was in use. A thermostat controlled the water heating, shutting off the gas when the water reached the desired temperature. The heater was fitted with the required valves. The street pressure is 68 lb. and the relief valve was set 7 lb. higher.

The thermostat failed to operate, the gas remaining burning and allowing the water to pass the boiling point and make steam, but the relief valve, which, remember, was set at 75 lb., did not function, the only escape being through the meter to the street against a head of 68 lb., damaging the meter, of course.

However, that was not all. Someone flushed the water closet on the second floor which was supplied from a fibre tank (low-down), opening a vent for the hot water and steam to escape, which it did, warping the tank out of shape. Think of what might have happened if my depart-

ment, like some others, required the use of check valves on the service and the relief valve did not operate.

By the way, I have learned that in some towns near Boston the Water Works Superintendent insists upon the use of a check valve, in the supply, on the house side of the meter to prevent the backing of hot water through the meter if the pressure boiler becomes super-heated. It often happens, I am told, that there is no relief valve on the system or that corrosion has eliminated its possibility of proper operation. The result is an explosion with damage to property and danger to life. I think it is a mistake to place the cost of replacing the rubber piston and warped cylinder of a meter above the damage caused by an exploded boiler. The State should prohibit absolutely the installation of check valves on supply pipes unless there is a by-pass with reversed check valve around the meter.

In closing, I want to place special emphasis on these points:

> First, that special studies should be made, having in view the possible reduction of the harmful action of water, and electric currents in service pipes and plumbing appliances.
>
> Secondly, that a State Board for the Regulation of Plumbing, which would forbid the use of some wasteful devices and regulate the use of others, would not only greatly benefit the house owner, ignorant of such matters, but would also tend to decrease the per capita consumption a great deal and thus probably postpone for some years the necessity for new water supplies.

Discussion.

Mr. J. M. Diven.* Mr. Heffernan's paper upsets a good many of our old theories. We had always supposed that grounding of alternating currents was perfectly safe.

What system of filter will be used to remove the taste and the odor caused by *algæ*? My experience is that filtration has very little effect on them.

Mr. Heffernan. I think that should be left to engineers, and that something ought to be done in regard to it. Each year about this time we have complaints caused by what we call *Asterionella*. I do not think that the plumbers or water-works officials really know what kind of pipe will give the best satisfaction taking into consideration the quality of the water, but a thorough investigation should be made or the water treated in some way. Now, that was a peculiar case at Newton. Brass pipe was already installed in the house, and, due to action of Newton water, had to be taken out and replaced with copper pipe. Then notice came to the owner of the property of the condition of the sponges which were used in the bath tubs. The sponges turned green. The matter was brought to the at-

* Secretary American Water Works Association.

tention of a Boston firm of chemists and samples of the water were analyzed, with the result that they found that the sponges, having an affinity for copper took it out of the water. Investigating further, the matter was taken up with Mr. Croker who put in an insulating device. The chemist stated there must be some electrolytic action there, and after installing this insulator they asked the telephone company and the Edison people to change their grounds from the house side to the street side. After that was done, samples were taken and tests were made; all traces of copper had disappeared and the sponges retained their clearness.

We have had experts from the Edison Company at our meetings, the grounding of wires has been gone into carefully and we thought everything was all right. But the tests Mr. Croker has made on Newton services since this case has come to his attention show that 75 per cent. of the services that he has tested show strong street railway currents, electric currents from the Edison or the telephone, with the telephone as the worst offender.

This is a subject which needs attention from this Association, and if any coöperation between the water-works officials and the telephone or the Edison people can work it out, it would be an advantage to us all.

Mr. Henry T. Gidley.* I entirely agree with Mr. Heffernan on the check-valves. I would not have one on any service if I knew it, because the few times the water might back through and spoil the piston in the meter is far preferable to what may happen from the use of a check-valve.

Another thing we are bothered with in Fairhaven is cheap plumbing. Houses are built there to sell, and cheap bathroom fixtures installed, with the result that they flush the full tank, no matter how big the tank is, while they could be fixed so that just enough water would flush the closet. A lot of water is wasted that way and then come complaints of the big water bills, because we are all metered. Then leaks occur at times, of course. The customers claim they never have any, but the water mark in the tank is a very good indication of where it ran over the overflow.

Mr. Diven. Another proposition was brought out by Mr. Heffernan which I think ought to be discussed — possibly not by the superintendents but by some of the experts,— and that is the removal of taste and odors caused by *algæ*, by filtration. In my own experience filtration has very little or practically no effect upon that. Taste and odors will go through any filters that I ever had any experience with. The only way to get rid of that is by copper sulphate, which we are not allowed to use here.

Mr. Frank Merrill.† I fully agree with all Mr. Heffernan has said in regard to the installation of check-valves on service pipes, and it is something we have never permitted for the reason that he has given. It is a source of possible damage, injury to the house plumbing and fixtures, and possibly the people in the house.

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* Superintendent Water Works, Fairhaven, Mass.

† Water Commissioner, Somerville, Mass.

Mr. Heffernan has referred to boilers as being of cheap workmanship, and I suppose he, like the rest of us, has had trouble with collapsing boilers. We have had considerable difficulty in this connection. If it is not getting too far away from the subject, I would like to ask what position he takes in reference to claims which are brought against his department by people whose boilers have collapsed through shutting off water in making repairs and for other reasons? We have had quite a few of these cases but have been able to avoid settlement of any damages, having taken the position that they should be fitted with the proper appliances to prevent collapse.

Mr. Heffernan. In answer to Mr. Merrill's question I will state that in two cases settlements have been made, although our conditions of water supply read that the town is in no way responsible for any damage to pressure boilers in cases of shut-down on the works. That is, in the cases mentioned we have allowed about 50 per cent. of the cost of replacement.

There is a law now in operation which relates to pressure boilers. Some few years ago certain manufacturers were marketing pressure boilers with a very weak shell. They were not built strong enough to stand sufficient pressure. The new law requires that all pressure boilers being installed shall be tested for 75 lb. working pressure, with a maximum of 250 lb., so, I feel that the liability of danger of collapse from syphonage will not be so great in the future.

There was one peculiar case settled by my town. In changing over from the brass fittings to lead-lined malleable-iron fittings in a two-family house containing two pressure boilers with no valves, the owner of the house was attempting to assist my plumber. There being no relief or vacuum valves it was necessary to open the hot water faucets. By mistake the owner opened the hot and cold water faucets on the first floor resulting in collapse of the pressure boiler on the second floor. So, because of the misunderstanding, we paid half the cost of new installation, although we do not intend to make a practice of it.

Mr. Francis T. Kemble.* Taking up the point made by Mr. Diven recalls to me that about five or six years ago we had a paper read before this Association at Boston by the head of the Bureau of Standards at Washington, in which he not only told us that there was absolutely no cause for any trouble from the alternating current but that he advised us to allow the electric lighting people to ground on our service lines. Following that I had a report made for our Company by the engineer who had been in charge of the wiring of the Manhattan Elevated in New York, who, I thought, would have a lot of practical training, as he had had, on those lines. His report was to the same effect. He advised us that grounding secondary lines from transformers and service lines would not cause electrolytic action on our pipe lines.

* Secretary, New Rochelle, N. Y., Water Co.

Mr. Caleb M. Savill.* It is my impression that a committee of the American Water Works Association, which has been considering this matter for some time, has advised the grounding on service lines.

Mr. Diven. You are right about that.

Mr. Patrick Gear.† I do not know whether we have better plumbers in Holyoke than they do elsewhere, but we have had but one boiler collapse in twenty years, that I know of. Probably we have better plumbers.

On the check-valve: I have told the manufacturers that they do not make a good one today. I have a meter on the floor now that has been there for some time. There are two checks, and they say they will put in two more if it will keep the hot water out of the boiler room. Any check-valve seems to be able to keep the hot water out of the boiler room but I have not seen a check-valve that would keep hot water out of a meter. If you throw up 100 lb. quickly against it you will close it if it is any good. But if it is at 90 lb. on both sides, and the water gets hot, it will come back into the meter, which causes trouble, and settlement is demanded for burning up the meter.

Mr. Heffernan. I suppose the action of the Metropolitan water probably is a little different from that of the Holyoke water. I claim that the automatic devices we are using in our water are practically useless, and I really think it a shame to have a law to provide for the installation of these devices and expect them to work when we are not getting suitable water. Some plumbers use a half-inch galvanized pipe and connect it to the pressure boiler with a brass valve. Why, the life of that pipe in Metropolitan water is only six years. When tubercles collect between fittings how do you expect these self-operating valves to function properly? There should be state control of plumbing fixtures.

In regard to the grounding of wires, electrical company experts, will tell us that no damage results from connecting their wires to our pipes.

I think our Association at this time should appoint a committee to look into the grounding of these wires on the water pipes.

Mr. Diven. Mr. Heffernan has brought up a very important point and something contrary to our ideas and practice, for the grounding of alternating currents, telephone and house lighting currents, has always been considered safe and is a very general practice. Mr. Saville has stated rightly, that the American Water Works Association passed a resolution approving such grounding. The National Board of Fire Underwriters has also approved such grounding, subject to certain restrictions. The matter is of too much importance to be passed over lightly and should have thorough investigation. To bring the matter before the Association more definitely the speaker moves the appointment of a committee to investigate the grounding of alternating current on house plumbing, such committee to act in conjunction with a similar committee of the American

* Engineer for Water Commissioners, Hartford, Conn.

† Superintendent, Water Works, Holyoke, Mass.

Water Works Association and with the National Board of Fire Underwriters, if those Associations appoint similar committees.

(The motion was seconded.)

Mr. George A. King.* We have had much trouble with the breaking off of the service pipe at the sidewalk cock, and it has seemed to me that it was owing to electrolytic action. I asked two experts who are connected with our Association the question whether the passing of electric currents through the service pipe had any influence on this electrolytic action, whether it increased it or not. One said it did, and the other said it did not. My experience in looking for an electrical engineer to make the survey has been that every one has had his schooling on the other side of the question. He does not care anything or does not know anything of the water-works side of it. Since Mr. Knudson's time I have not known of a man who has sided at all with the water-works people. Perhaps they are all honest and get the proper view of it, but it does not seem to me that they have.

Now, as to Mr. Heffernan's contention that the water should be such that this action will not take place, I would like to ask an expert if any water that is wet will not cause that action?

President Barbour. There is a motion before the meeting. It is moved that a committee be appointed to investigate this question of grounding alternating current on house plumbing, to coöperate with a similar committee of the American Water Works Association.

Mr. King. I move to omit the word "alternating," and have it refer to all current.

President Barbour. Do you accept the amendment?

Mr. Diven. Yes.

President Barbour. The motion stands without the word "alternating." If I may interject just one word: If you vote in favor of this question and this committee when appointed sends around a questionnaire, let every man who votes "Yes," say to himself when that questionnaire arrives, "I will answer;" otherwise, vote. "No."

(The question is put and carried.)

Mr. Saville. Regarding the committees that have been appointed by other Associations on this matter, I can't speak from experience, I know of none of their workings, but I do know that the American Water Works Association Committee is not made up of experts who are favorably disposed toward electric wires. For instance, my good friend, Mr. E. E. Minor, the Superintendent of the New Haven Water Company, which is a large private corporation, is a member of that Committee, and I am quite sure that he is not proposing or advancing anything which he thinks will benefit an electric light or other industry to the detriment of the interest of his own company. So that I think the matter has been looked into

* Superintendent Water Works, Taunton, Mass.

by that Committee in a very open and fairminded way. Generally, I am finding that a growing tendency for coöperation and harmony between different corporate interests is much more the rule than in the past and that identity of interest is accomplished more for the good of all than can be had from the individual action of many.

MR. DIVEN. I understand they are only investigating stray railway currents. Unfortunately, there is a movement on foot now to disband that Committee.

MR. GEORGE W. FULLER.* Mr. Chairman. The treatment of water supplies to eliminate tastes and odors is quite a proposition. Filtration will accomplish a great deal. That is not the whole story, however. Filtration will strain out organisms which by themselves produce odors of growth, in some cases while the organisms are still living. As some organisms disintegrate they release penetrating oils of various kinds. These oils in some instances are as penetrating as the oil of peppermint but are characterized by objectionable tastes and odors.

Aeration has been found at some plants to remove 60 to 80 per cent. of tastes and odors of this type. Filtration by actual physical separation will remove odors of growth. Odors of decomposition such as are associated with stagnant waters can be very largely, if not completely, removed by aeration.

In some instances aeration prior to filtration causes disintegration of organisms so as to intensify tastes and odors which would not be noticed at all if the undisintegrated organisms were separated from the water by filtration.

The main point here to stress is that filtration and aeration in suitable combination will go a very long way towards keeping a water supply free of objectionable tastes and odors due to the growth of micro-organisms. These treatments can be used in conjunction with copper sulphate, as Mr. Diven suggests. And with this combination there are many plants which show that a perfectly satisfactory water supply may be obtained in the face of what might seem to be great difficulty.

The corrosion of service pipes and other metals by water varies quite widely, depending upon the amount of various constituents present in the water. Carbonic acid is one of the most important elements to be considered in relation to the causation of corrosion. It has not been determined by analysists under ordinary circumstances and rarely appears in the records of any State Board of Health. It has been studied, however, for certain ground waters and in connection with the performances of certain reservoirs which have been stagnant at intervals.

Some waters contain so much carbonic acid that they quite readily attack not only uncoated iron but also lead. In the case of waters which are quite hard lead pipes do not give much trouble because there is

* Consulting Engineer, New York.

formed quite quickly a natural coating on the inside of the pipe consisting of basic carbonate of lime.

For some water supplies, filter projects are arranged so that corrosive properties may be kept under control partly through the removal of carbonic acid either by aeration or by the addition of lime, or by both. Such arrangements are being developed in the new filter project at Buffalo.

There is a lot of information available in this country and in Europe, particularly England, on the corrosion of metals by waters of different types. We have recently been dealing at Memphis with a problem involving the treatment of a well-water supply which contains over one hundred parts per million of free carbonic acid. It will be removed by aeration and by liming in conjunction with an iron removal plant.

It takes such unusual waters as this to cause water-works men to look over the field of available data and it is really surprising how much valuable information there is representing the experience of thoughtful water-works men in different sections of the world.

What we really need is to get information set forth in a brief, understandable way so that progress along practical lines may be more rapid in the future than hitherto.

It is educational work along this general line in the various branches of the water-works field which is engaging the attention of the Council on Standardization of the American Water Works Association. It is not my idea that these several committees are going to develop great discoveries. Indeed it is not necessary that they do so. Coöperative and coördinated committee work has its greatest value along educational lines so that the practical knowledge of water-works men as a group will become greater and greater as the years go by. I always enjoy attending the meetings of the New England Water Works Association. Many of its problems as discussed are quite different from those found in other sections of the country and yet there are other problems that are quite similar everywhere. I believe that all water-works men owe to their chosen field of work a substantial effort in support of advancing knowledge, and one of the first things to brace up is a better understanding of past experiences.

Work of this type cannot be limited to any one association or to any one group of workers. We want theory and we want practice, but we want the accomplishments along both lines set forth in a way that will be better understood by water-works men as a whole.

The field is so big that there should be no occasion for petty jealousies between different associations, nor any needless overlapping of committee work. What we really need is strong coöperative action and it is gratifying to me, as Chairman of the Standardization Council, that such coöperation is being developed between the Council Committees and the New England Water Works Association.

Mr. Heffernan. There were two points brought out in my paper on which I would like to get the opinion of some of the members here.

One is as to the feasibility of the control of plumbing. There was nothing said about that or with regard to stopping the waste of water. Mr. Fuller's remarks were in regard to the action. In my paper, I brought out the fact that we are using Metropolitan water, and that we had to abandon lead service pipes.

Different concerns recommend different materials for pipe. But come right down to the facts. Consider the kind of water you are getting; use the material that is fitted for that water. I claim that lead pipe should not be used, and the State Board of Health will say so too. But still lead pipe is being used extensively. Why? The fact should be made clear that lead pipe is not fit to use to any extent with the Metropolitan water. I have proved that.

Mr. Diven. Among the committees of the Standardization Council of the American Water Works Association is one on service pipes and one of the questions under consideration by that committee is the degree of hardness necessary to make the use of lead service pipes safe. It is well-known that absolutely, or even very soft, waters act on lead and make their use with lead pipes dangerous. There is very little information in this country on the subject and clear cases of lead poisoning are very rare so far as we know. Mr. M. C. Whipple of the committee is making a study of this and collecting information, both in this country and in England, where the subject has been given more attention than here.

Mr. Percy R. Sanders.* In Concord our water supply is very soft so that we can't use lead pipe. We use cement-lined wrought-iron pipe for all of our services and then for the connections, use tin-lined lead pipe. Sections from the tin-lined lead pipe connections that I have taken up that have been in for fifty years show absolutely no corrosion or wear on the inside. It seems to hold up and do the business.

Mr. Herbert C. Crowell.† In regard to pressure boilers. For a good many years we have been looking for some kind of a vacuum valve and a pressure valve which would avoid the trouble we have in a great many places. If any member here knows of a vacuum valve which will always work on a pressure boiler I would like very much to hear what it is; also a safety valve.

Mr. Heffernan. In answer to Mr. Crowell I will say that I have not much confidence in any automatic device depending upon action to keep the water from receding — that is, with Metropolitan water — on account of galvanic action. There are some valves on the market that will work with some waters. I have talked with plumbers and the best tradesmen in that line, and there is a valve, a Mr. Smith a plumber of Boston, has patented, the action of which depends on temperature.

Mr. Henry A. Symonds.‡ Does the service pipe always, when open, afford sufficient relief if gas heater is left burning?

* Superintendent Water Works, Concord, N. H.
† Superintendent Water Works, Haverhill, Mass.
‡ Consulting Engineer, Boston, Mass.

Mr. Heffernan. If the boiler is made strong enough I should say yes.

Mr. Crowell. I think, Mr. President, a great many times pressure boilers have caused trouble that way.

Mr. A. O. Doane.* I would like to ask Mr. Heffernan if he has ever run across a valve called a "Stack valve," where the safety valve is combined with the hot water faucet, the idea being that the ordinary safety valve as applied to any pressure boiler is not reliable because it corrodes and becomes inoperative so that the boiler is likely to blow up before the valve works. Now, with the Stack valve there is a safety valve combined with the hot water faucet, so that every time the faucet is opened this valve works, and therefore there can be no sticking or corrosion. We have one of those installed in a house, and as far as I can see it would afford relief. But there is some trouble with the operation of the valve as a faucet. It is not sure to shut off tight. It has a metallic seat, which is not as tight as a rubber or fiber seat. But as far as I can see, the valve is kept entirely free; there is no sticking. It operates as well as any common safety valve.

Mr. Hefferann. The installation of a Stack faucet gives one a chance to use the faucet daily and there is no reason for it to stick. But those faucets do give some trouble by leaking. I think that is the best relief valve there is on the market today, because of the positive action of a faucet that is used every day.

Mr. Doane. The leakage is not serious. It drops a few drops now and then. But it seems to me it is a safety measure.

Mr. Heffernan. It is the safest relief valve, I believe.

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* Division Engineer, Metropolitan Water Works.

CEMENT FOR WATER PIPE JOINTS.

By William Wheeler.*

[*January 9, 1923.*]

This paper — prompted by suggestion of a member of your Executive Committee that something about the use of cement for joints of cast-iron force mains at Winchester, Kentucky, might interest the Association — has been further " aided and abetted " by instructive discussions at recent meetings of the American Water Works Association, and the New England Water Works Association, upon substitutes for lead for jointing cast-iron water pipe,† in which discussion nothing appears to have been said about the use of cement as a substitute. Our treatment of the subject is also approached along suggestive lines afforded by two instructive papers with discussion, appearing one in a recent volume of the *American Society Civil Engineers*‡ and the other in one of the *Journals, American Water Works Association*,§ which described some early experiences and later examples of the use of Portland cement for cast-iron pipe joints in California and other western states.

Hydraulic cement for water-pipe joints is not a modern conception, nor is its use in bell and spigot joints of pipe for carrying water under low pressure of recent origin or beginnings. For example, the use of hydraulic cement for the joints of B. & S. pipe for sewers and drains probably dates as far back — and perhaps much farther — than does the use of cast-iron water pipe with bell and spigot ends; but we recall no suggestion in history or tradition that the use of cement in joints of earthen pipe for carrying waste water under low or no heads, prompted its use contemporaneously for the B. & S. joints of cast-iron pipe supplying water under high heads, — notwithstanding the excellent qualities of cements made and used both in America and in Europe since more than a century ago.

But whatever earlier history may disclose on that point, members of this Association, who are themselves living witnesses and indeed factors of modern history on that subject, well know that the " natural " hydraulic cements which constituted nearly the entire output of cement made in this country until about thirty years ago, were used extensively from about 1855 to 1890 or later in the construction of cement-lined and covered-

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* Consulting Engineer, Boston, Massachusetts.

† " Lead Substitutes for Pipe Joints." *Amer. W. W. Ass'n.* Topical discussion at Philadelphia Convention, May 18, 1922. *Journal Amer. W. W. Ass'n*, Vol. 9, pp. 868–873; and " Experiments with Substitutes for Lead for Jointing Cast Iron Pipe." Stephen H. Taylor, Supt., New Bedford Water Works, with discussion. September, 1922. Journal, N. E. W. W. Ass'n, Vol. XXXVI, pp. 375–384.

‡ " Cement Joints for Cast Iron Water Mains," by Clark H. Shaw, *Trans. Amer. Soc. C. E.* Presented April 18, 1917, Vol. LXXXIII, 1919–1920, pp. 276–304.

§ " Cement Joints for Cast Iron Water Pipe," by George W. Pracy, *Journal Amer. W.W. Ass'n*, 1920, Vol. VII, pp. 436–439.

wrought-iron pipe for water mains, the joints of which were also made with such cements; and that such use has continued even to this day in numerous cases where "justification by faith," resting on example and good works, has borne fruit from such beginnings.

Among some of the early works in which cement-lined and covered-wrought-iron pipe was used and substantial parts of which still remain in service are those at:

Plymouth, Mass.

In 1854 the town purchased the privately-owned plant which from 1796 had supplied water by gravity "through 2 to 4-in.-pitch-pine logs," — and "abandoning old logs," then first laid wrought-iron and cement pipe in 1854.* Since then it has continued to lay and use cement-lined and covered pipe up to the present time, comprising:

Laid in 1855, 1.40 miles of 20-in. and 10-in. conduit pipe; besides mains of smaller sizes.

In use, 1883, 20.37 mi. from 20-in. to 2-in.
In use, 1890, 28.20 mi. from 20-in. to 2-in.
In use, 1921, 56.98 mi. from 30-in. to 2-in.

Ordinary average pressures about 40 to 60 lb. These pipes have been of two or three different types of barrel and joint construction, with variable merits as to serviceable life and reliability.

Portland, Me.

Two gravity conduits from the intake and supply works at Sebago Lake to Portland, comprising:

About 14.40 mi. of 20-in. pipe, laid in 1868–69,
3.46 mi. of 26-in. pipe, laid in 1875–76,
and 10.50. mi. of 24-in. pipe, laid in 1878–79,

or a total of 28.36 mi. of pipe, the lower levels of which have been operated under maximum hydraulic heads of 90 lb. more or less, depending on friction losses and other variables determined by conditions of supply and of service distribution.

Concord, N. H.

Gravity conduit and distribution mains of cement-lined and covered-wrought-iron pipe, comprising:

About 3.5 mi. of 14-in. conduit laid 1872,
About 10.0 mi. of 12-in. to 4-in. mains, 1782,
About 9.0 mi. of 12-in. to 4-in. mains, 1873–81,
About 11.07 mi. of 18-in. to 4-in. mains, 1882–87,

of which there is now in use all and only the 11.07 mi. of cement-lined pipe laid in 1882–87 as noted above. Ordinary average pressure about 46 lb.

* *Manual of American Water Works*, 1889–1890, p. 76. Engineering News Publishing Co.

Waltham, Mass.

Leading and distributing mains, comprising: about 0.50 mi. of 16-in. pipe, 1.50 mi. of 12-in., and 11.10 mi. of 10-in. and smaller sizes, all laid in 1872; and extensions aggregating about 9.50 mi. more in 1873 to 1886 or '87, when the use of such pipe for further extensions ceased. These mains were first used under ordinary or static head of about 60 lb. per sq. in. High-service pressure followed later, and most of the cement-lined and covered pipe has now been replaced by cast-iron mains.

Concord, Mass.

Original gravity system of wrought-iron and cement supply and distribution mains, laid in 1872-88, comprised about 21 mi. of 10-in. to 3-in. sizes, of which 16.4 mi., or 78 per cent. in length and over 90 per cent. of weighted values, are now in use. For subsequent additions and renewals, cast-iron pipe has been used. Replacements of cement-lined, with cast-iron pipe have been made chiefly to repair damages arising from sewer construction and to increase and extend service capacity.

Newburyport, Mass.

Original force and distribution mains laid in 1881–82, with extensions to 1889–90 then aggregated about 26 mi. of cement-lined and covered pipe, of which about *eight* miles are now in service. Ordinary pressure about 55 lb. Cement-lined pipes have been replaced with cast-iron pipes in part, to provide larger capacities, and in part because of injuries incident to sewer construction.

Watertown, Mass.

Original force main and distribution system aggregating about fourteen miles of 12-in. to 6-in.-pipe, laid in 1884; increased by extensions to upwards of 20 mi. in 1890, of which 9.70 mi. now remain in service.

Maximum pressure with full standpipes, before taking water from Metropolitan supply, was about 100 lb.; and with Metropolitan supply, about 110 lb.

Gloucester, Mass.

Original force mains and distribution system of wrought-iron and cement pipe laid in 1885, with extensions to 1895 — when the town purchased the property — then aggregated net about 23.5 mi., of which 14.5 mi. are now in service. Of the nine miles of wrought-iron and cement pipe replaced by cast-iron pipe, some below tide level was damaged by sea-water, and other portions were replaced to provide greater service capacity. Ordinary pressure about 70 lb. Maximum, 80 lb.

Such are a few examples, taken from the hundreds of water works in New England and other eastern states, in which such pipes were com-

monly used from sixty-five to thirty-five years ago, but which require no further comment for the prime object of this paper.

Nevertheless, by way of passing reference to the history and serviceability of cement-lined and covered-wrought-iron pipe in general, we should not ignore the fact that in many, perhaps in a majority of the works in which some form of such pipe was used, most of it has been taken out or abandoned, and replaced with cast-iron pipe; and this has been done not alone or mainly, in our judgment, in order to substitute pipes of larger capacity, or to replace pipes injured by other construction, but rather from results of inadequate specification of materials and workmanship, or lack of scrupulous care and supervision of the original construction of the plants, in the interest of their ultimate owners.

Keeping in mind, however, *cement joints* as our subject, it should also be noted that so far as known to us, in few, if any, of the works named above have the cement joints disclosed inherent weakness, or general inferiority to joints of cast-iron pipes made with lead or other substitutes; and we believe this to have been generally true of the joints of cement-lined pipes in other works that have been replaced by cast-iron. Upon this point it may be interesting and suggestive, even at this late date, to quote from a personal letter written nearly fifty years ago by Hon. Phineas Ball, — an engineer of high character and distinction, with wide experience in water supply and other hydraulic works. He wrote July 18, 1873:

"Cement, at least the American Hydraulic Cement, appears to possess the property of completely protecting and preserving wrought iron, preventing its oxidation apparently for an indefinite period.

"The points wherein they are most likely to fail, is from the imperfect application of the cement in the lining or covering. These imperfections may be thus stated:

"*First.* Imperfect lining or covering, whereby some portion of the iron is left to come in direct contact with the water on the inside, or moist earth on the outside. These exposed spots are sure to rust through.

"*Second.* By careless mixing of the mortar, by which a portion of it may be applied too largely sanded, whereby the mortar has not cement sufficient in its texture to give the required protecting property.

"*Third.* Injury to the cement covering of the pipe by careless back-filling of earth over them. This occurs most frequently in soil largely filled with cobble-stones, and is the result of letting the stones fall upon the pipe, whereby a small portion of the covering is knocked off from it. All spots uncovered are sure to rust through.

"*Fourth.* The careless mixture of clay, loam or ashes with the cement mortar, so as to form a bunch or patch of this material touching the pipe. These points will rust through. All portions of the pipe thus exposed to oxidation will rust out in from three to five years, according to the thickness of the iron, and the advantageous conditions under which they are situated, promotive of rust.

"This pipe requires great care in laying, to see that the simple principles on which its durability depends are faithfully applied. Its success requires good material, and good old-fashioned downright and outright,

honest and faithful work from beginning to end, and then one is reasonably sure of a permanent job. *The joints sometimes give trouble, especially if cement of an inferior quality is chanced to be used in the filling.* (Italics are ours.)

"But all the trouble I have ever seen with joints leaking, I do not deem nearly so serious as the defects from inferior workmanship in the making and laying, and sometimes poor cement."

The cement-lined pipe at Concord, Mass., laid in 1874–84, was designed for a gravity supply under static heads not exceeding 40 to 45 lb. per sq. in. About thirty-two to thirty-five years after the first of that pipe was laid — that is, in 1906–09 — the pipes were tested out, section by section, by pumping directly into them through a Duplex steam pump under added pressures of from 60 to 70 lb. This was done in order to discover and eliminate any weak points and defects therein, and so determine their suitability for carrying pressures of 100 to 105 lb., or 150 per cent. more than they were originally designed to carry. These tests, made in anticipation of establishing high service works, disclosed no inherent weakness of the joints. Superintendent Robinson, who conducted the tests, states that in the fifteen years since elapsed, no significant joint defects have appeared.

The history of such experience during forty to sixty years past with our natural hydraulic cement for joints of wrought-iron pipe, affords added significance as to the adaptability of Portland cements for joints of cast-iron pipe, particularly in the light of some comparative considerations that readily suggest themselves:

(1) The joint spaces between either the sleeves or the unlined socket ends of the wrought-iron pipe shells, and the abutting ends of the lined but uncovered shells, lacked the annular groove that is provided in the sockets of cast-iron pipes, to better secure the joint material under high pressures.

(2) The special castings ordinarily used with cement-lined pipes were of cast iron, with sockets having usually no annular groove for securing the joint material, and sometimes specials of the standard forms of bell and spigot type were used, with joint room suitably enlarged. But in either case such experience affords good examples of the use of natural cement for cast-iron water-pipe joints for more than half a century, during which they have withstood all the tests of service to which lead joints might have been subjected, under similar heads and conditions.

(3) Among the characteristic qualities of cement, and more particularly, of Portland cement, which affect its adaptability for water-pipe joints, as compared with those of lead for example, are:

(*a*) Strength in compression — or resistance to crushing, or to impairment of the joint by its deformation, — superior to lead.

(*b*) Adhesion to, — or surface friction under pressure, in contact with, — coated surfaces of cast-iron pipe, affording resistance to sliding

under stresses by expansion and contraction of pipes, through changes of temperature, or by earth disturbances, — superior to lead.

(*c*) Comparative equality of linear expansion with that of iron, under temperature changes, — superior to lead.

(*d*) Immediate and constant equality of temperature with that of the pipe, while joint is being made.

(*e*) Expands slightly in setting, tending to prevent leakage, whereas lead contracts in cooling.

(*f*) Non-conduction of electricity, affording better insulation at joints.

(*g*) Intimate conformity of surface contacts with walls of joint space, under pressure by calking and setting, tending to prevent displacement and leakage, — superior to lead.

(*h*) Elasticity and resilience, within elastic limit of cement in compression, while confined within and adhering to the cast-iron walls of the joint space, affording adaptability to joint flexure without rupture within such limit.

Some characteristics of cement which contribute to its chief merit as material for cast-iron pipe joints, may in other respects be objectionable. Thus the compressive strength and hardness of cement without malleability, may suggest a rigidity which might not yield by flexure at the joints to changes of alignment, or of position of the pipe, sufficiently to conform to movements caused by earth settlement, vibrations, or variations in temperature, without disrupting the joint or breaking the pipe itself.

It would, however, appear from the experiments and experience with cement joints in the states along our Pacific coast, as described by Mr. Shaw and Mr. Pracy,* that the elasticity and resilience of cement when well calked and well set under compression between the walls of the joint space, as already suggested, have allowed flexure ample for joint deflection within the ordinary requirements of those cases. And if in more extreme cases the joint ring may crack, or even disintegrate, at its free end or deeper in the socket under extreme flexure, it would nevertheless appear to be so securely held in place under high compression between the rough surfaces of the socket and spigot that its volume must remain substantially unchanged in amount, and so slightly in form that any interstitial checks or hair cracks therein would be too minute, and lacking in width and continuity, to permit appreciable leakage. Moreover there are comparatively neutral portions or sections of the joint ring between its ends, at which compression stresses — caused by bending or deflection at the joints — are at a minimum; and where, therefore, injury to the joint material would occur, if at all, only under deflections greater —presumably much greater — than would suffice to cause initial disturbance or injury at the face of the joint.

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* See footnotes (‡) and (§), page 62.

Upon the question of permanence and stability of cement joints for cast-iron mains laid in city streets, where earth-fills and sewers below, paving above, and other utility mains and structures contend for safe and convenient occupancy and use of the public ways, it may be noted that the joints of cast-iron gas mains in Boston have for many years — to a large extent — been made with a stiff wet mix or paste of either natural cement or of Portland cement.

The engineer of the Boston Consolidated Gas Company, Mr. Goodwin, informs me that the Company has been using cement for forty years or more, successfully and without notable difficulty or objection, and still uses both cement and lead for the joints of its cast-iron mains. He states that more than half their joints are made with cement, that they give no trouble by rupture or impairment, leak less than lead joints, and that they are " cut out about as easily as lead."

It was against such backgrounds of experiment and experience with cement for pipe joints, and in the light of the characteristics which seemed to determine its fitness for such purpose, that Portland cement was adopted in 1921 for the work at Winchester, Kentucky.

Cement Joints for Force Mains at Winchester, Ky.

The Winchester Water Works Company owns and operates the plant which supplies the City of Winchester — county seat of Clark County, Ky. — and its vicinity. The city stands on the divide between the Licking and Kentucky Rivers, — the Kentucky River at its nearest point being about eight miles and a half southwest of the city.

The original works were built in 1891, taking water from impounding reservoirs on Lower Howard Creek, at about four miles southwest of the city boundary — which is a true circle, one and a half miles diameter, having its center at the County Court House.

The water is filtered by the rapid or American system, and pumped by two compound Duplex pumping engines of 1 m.g.d. capacity (for alternate service) through a cast-iron force main (originally 10-in.) to the grid of distribution mains, and thence through it by 10-in. and 12-in. mains to a wrought-iron standpipe, 75 ft. high, having its base at about elevation 1 033 ft. above tide water, and 275 ft. above the clear water basin at the Pumping Station, making an ordinary pumping lift of about 120 lb., plus friction in the mains; and 25 to 35 lb. more during pumping for fire service.

Acute shortages of water supply from the creek and reservoirs occurring in the autumns of the dry years 1913, 1918 and 1921, determined the necessity of getting a supplementary supply from the river, preferably at a point about 4.30 mi. farther southwest of the present station, near Government Dam and Lock No. 10; and with the ultimate purpose of

establishing there, permanent works adequate for supplying all future requirements of the city and its vicinity.

In the face of certain major and dominating conditions that could not then be determined or forecasted, including those relative to acquiring Federal permit and authority to take water from the river, and to develop power for pumping it; and the elements of time, place, and quantity hanging thereon, — the primary steps adopted for immediate action, were:

First. To take up the 10-in. pipe of the original force-main, — a half-mile of which had been paralleled with 12-in. in 1906, and replace it with 12-in. pipe. This work was done in six stages or construction sections. Starting at the lower end of the work, at the point to which 12-in. pipe had been laid in 1906, 10-in.-spiral-rivetted-steel pipe was used for by-pass lines where necessary, connected through suitable fittings with the 12-in. substituted pipe and the old 10-in. pipe to be taken up, whereby the supply was maintained while the successive sections of old and new pipe were progressively taken out and replaced.

The spiral-rivetted pipe and fittings were furnished by the American Spiral Rivetted Pipe Works. Most of the work was done between August 1, and December 31, 1921, and it was substantially finished in May, 1922. This main is referred to as " Force-main No. 1."

Second. The next step was the installation of a force-main of cast-iron pipe from the Kentucky River to the supplying works at the pumping station. For this purpose the 10-in. pipe taken up from the original force-main to the city, was used as far as it would go toward the river; and from thence to a tentative site for temporary or emergency connection with the river, 12-in. pipe was used, save for about 515 ft. of spiral-rivetted-steel pipe used as a temporary space-filler, making a total length of 22 210 ft.

It will be understood that this combination of kinds and sizes was required to meet immediate emergency needs, and with the intent to either replace or duplicate the 10-in. with mains of larger size, as future need and conditions may require. The work on this main continued from May 23 to December 5, 1922; and it will be referred to as " Force-main No. 2." Under present conditions it will be used to furnish emergency supply to supplement that from Howard Creek; and will operate under a maximum head of about 400 ft. static, plus friction head. Under direct pumping from the river to the city distribution system, with the standpipe full, — should such service ever be required — the maximum would reach about 523 ft. static, plus friction. Such use however is not likely to occur under the most effective and economic plan for design and operation of permanent works.

After completion, this line was tested under a maximum head of 225 lb., or 523 ft. static, at its lowest point; and about 105 lb. or 243 ft. at its high points.

The work was done under the general supervision of C. F. Attersall,* Superintendent of the Works, coöperating with J. M. Cashman,† having immediate charge of the field work.

The joints were made with neat Portland cement, moistened and mixed with water in the ratio of 1 lb. of water to 13.5 lb. of cement. The average weight of cement used per joint, including waste and loss, was:

For 12-in. joints, 8.3 lb. per joint.

For 10-in. joints, 6.9 lb. per joint.

The percentage of water to cement was 7.4.

Mixing. The cement was mixed in batches of the unit quantities, with water in the ratio above stated, in a galvanized iron pail, and thoroughly stirred by trowel and by hand, using rubber gloves to protect the mixer's hands while kneading it and breaking up the small lumps of cement in the process. It was then carried by the mixer and dumped into a pail of the same sort, one for each cement calker, of whom there were usually three in a gang.

Adjusting and Making the Joints. Meanwhile the pipes have been aligned and adjusted at the joints, yarned with dry jute packing, and thoroughly calked in the usual manner by the yarn calker, so as to leave $2\frac{1}{2}$ in. or more for the depth of the cement joint. Then a cement joint maker and calker spreads across the trench under the joint, a piece of rubber or oilcloth, about 2 ft. wide by 3 ft. long, to catch any cement that may drop in making the joint, and places his pail of mixed cement on the spigot end of the pipe before him, as he straddles the socket end of the connecting pipe; and with rubber gloves on, he fills the joint with cement as full as he can by hand and, with the calking iron, rams it into the joint as hard as he can without using the hammer. This operation by hand is repeated four to six times, the hammer being used, however, after each filling of the joint except the first, the cement being thereby calked and driven under the blows of a $3\frac{1}{2}$-lb. hammer as thoroughly as in calking a lead joint, until little or no impression is made upon the face of the joint.

As soon as the joint is finished, the calker removes any dirt or foreign matter that may have fallen upon the cloth, dumps into his pail any cement dropped upon it while making the joint, and moves on to his next one.

The average time of so making either a 10-in. or a 12-in. joint was about twenty-five minutes, including moving from one joint to another. The time used in making 10-in. joints was increased somewhat because of the greater variation in depths and thicknesses of the joint space, than of the 12-in. pipe.

Covering the Joint to Retain Moisture While Setting. After the calker passes on from a calked joint to his next one, the mixer fills the trench with earth sufficiently to cover the calked joint to a minimum depth of about six to eight inches, in order to retain the moisture in the cement while it is setting.

* Member of American Water Works Association.
† Member Boston Society Civil Engineers, Assistant with William Wheeler.

The Gang of Joint Makers. In making up the joints it was found most effective to use a gang of five men, as follows:

(*a*) One man to do all the mixing of cement; pass and distribute it to the cement calkers; and to cover the joint with earth (to retain moisture) immediately after it has been calked.

The mixer was paid at the rate of 25 cents per hour.

(*b*) One man to align and center the pipe at its joints, and yarn them; and, if time allows, then to help out the three cement joint makers and calkers.

The yarner was paid $27\frac{1}{2}$ cents per hour.

(*c*) Three men, working solely at making and calking the cement joints during such times as joint making was going on. When not employed in joint making these men were used on other work to the best advantage, according to their fitness and capacity therein, such as trenching, rock work, pipe laying, back filling, etc.

Cement joint makers and calkers were paid $27\frac{1}{2}$ cents per hour.

Such a gang of five men was under the direction and oversight of a foreman, having general charge of the work on the pipe line; and foremen were paid 35 cents per hour.

Calking Irons, Special. The tool end of the blades of the calking irons are about $4\frac{1}{2}$ in. long and $1\frac{3}{4}$ in. wide, with transverse sections conforming to the outside of the pipe on which they are to be used. These were provided in four different thicknesses, of about $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in. and $\frac{5}{8}$ in. respectively, for use according to the range of thickness of the annular joint spaces. The calking end of the blade should be well squared, so as to maintain its full end-face area for effective bearing on the joint.

Cost of Materials. In making up the cost of the joints, the labor costs are computed at the wage rates above stated, and 3 per cent. added for liability insurance. The unit costs of materials and supplies used, delivered at the trench, were:

Cement at 57 cents per bag, net.

Jute yarn at $6\frac{3}{4}$ cents per lb.

Rubber gloves at a total cost of \$53.50, distributed on the number of joints entering into the estimate, with gloves enough left to complete the work, or use elsewhere.

Calking-tools, special work, at 1 cent per joint.

COST PER JOINT.

Labor.

Size.	Foreman.	Yarner.	Mixer.	Calker.	Liability Insurance. 3 per cent.	Totals per Joint.
(New) 12 in.	\$0.05	\$0.03	\$0.10	\$0.12	\$0.01	\$0.31
(Old) 10 in.	0.05	0.03	0.10	0.12	0.01	0.31

MATERIALS.

	Yarn.	Cement.	Rubber Gloves.	Special Calking Tools.	Totals per Joint.
12 in.	$0.023	$0.07	$0.014	$0.01	$0.12
10 in.	0.019	0.06	0.012	0.01	0.10

LABOR AND MATERIALS COMBINED.

12 in., per joint,	$0.43
10 in., per joint,	0.41

Method of Measuring Joint Leakage. Each section of force-main No. 1 was plugged at both ends before turning the water into it. A $\frac{3}{4}$-in.-tap was then made into the adjacent end of the section previously laid and already under pressure; and another $\frac{3}{4}$-in.-tap into the section to be tested, and these taps were joined through a $\frac{3}{4}$-in.-connecting pipe, on which a $\frac{5}{8}$-in.-Trident meter was installed. After the reading of the meter was recorded, the water was turned on and the section of pipe to be tested was filled. When the meter stopped, showing the pipe line to be full, the meter was again read, — the difference between these two meter readings showing how much water was used for filling the section. The section under test was then kept under pressure from 5.5 hours as a minimum, up to 50.5 hours, depending upon the time that could be allowed therefor before putting the particular section under test into service. At the end of that time another reading was taken, whereby the leakage during the test was determined. While the test was going on, the engineer and his assistants removed the earth from the joints and inspected them for any visible evidence of leakage.

Out of 196 joints in the first section tested, seven showed efflorescence shortly after the main was full, the face of these joints being moist with a white frothy exudation. On rubbing one's finger over these joints, the exudation disappeared and did not show up again, although the joint remained moist for as long as twelve hours, after which it usually dried out and no further moisture appeared. Where such white foam was not rubbed off, it dried and left a whitish coating, such as often appears on the surface of recently-laid cement work.

The other sections of force-main No. 1 were tested in the same way, and showed substantially the same conditions at the joints. The several tests were made under minimum pressures ranging from zero to 125 lb. and maximum pressures from 65 to 160 lb. per sq. in. The elapsed time between making the last joint of each section and first turning on the water for testing it ranged from 20 hours to 40 hours, and averaged 29.3 hours. The last joints of the several sections were finished in the following months respectively, namely: section 1 in October, section 2 in November, sections 3 and 4 in December, 1921; and sections 5 and 6 in May, 1922.

The weighted average leakage per foot of joint, in all tests of the sections of force-main No. 1 — omitting the tests in which some leakage

occurred elsewhere than at the joints — was at the rate of 0.50 gal. per day, as registered by the meter.

Force-main No. 2, laid in 1922, was tested only in small part by sections. In one of the sections there was leakage by a cracked pipe, and in others at gate-valve stuffing-boxes. These were repaired and the force-main completed late in November; and in December, sixteen days after the last joints were made, the entire force-main, 22 210 ft. in length, was subjected to test. This length comprised 2 898 ft. of 12-in., and 18 797 ft. of 10-in. cast-iron pipe, having 2 115 joints, and 515 ft. of 10-in. spiral-rivetted galvanized pipe, having 18 joints with rubber gaskets, — used as a temporary space filler. This test continued 117.5 hours, under pressures of about 105 lb. per sq. in. along its higher levels, and 225 lb. at its lower levels. The weighted average leakage for all the joints as registered by the meter, was at the rate of 0.38 gal. per day per foot of cement joint, — upon the assumption that no leakage occurred at the joints of the spiral-rivetted pipe — which assumption however was not strictly true. Further details of the tests are shown in the accompanying tabulation, page 74.

A few quotations from the opinions of those whose earlier experience with cement joints have been referred to, may be here recorded as fitting close of the chapter we now add to their testimony:

Clark H. Shaw. "A brief history of the use of this joint establishes the fact that this method of construction has long since passed the stage of experiment and has been proved to be an economic factor in laying such mains." *

H. B. Lynch. "This method of calking joints in cast-iron pipe deserves a wider use not only on account of its low cost, but because it makes a better joint at least when no considerable movement of the pipe is expected after it is laid."†

George W. Pracy. "Taking all things into consideration, it is believed that the cement joint has come to stay. Improvements over the present methods of making the joint will undoubtedly be made, but even at the present cost they are cheaper than any other joint known, and from all the experience out here on the Pacific coast, they are entirely satisfactory."‡

October 16, 1922, when the work at Winchester was substantially finished and every joint inspected, save for connections at the river end, awaiting advices from the War Department, Superintendent Attersall wrote:

"To date we have found but one leak in cement joints, and this one because the pipe was permitted to slip before the cement set. I think this is a splendid record for the nearly eight miles of mains laid with this type of joint."

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* Trans. *Amer. Soc. C. E.*, Vol. 83, p. 276.
† Tran. *Amer. Soc. C. E.*, Vol. 83, p. 301.
‡ *Journal Amer. W. W. Asso.*, 1920, Vol. 7.

WINCHESTER WATER WORKS — WINCHESTER, CLARK CO., KY.

LEAKAGE TESTS OF PORTLAND CEMENT JOINTS FOR CAST IRON FORCE MAINS. 1921–22.

Size of Pipe. In. (1)	Section and Test. Nos. (2)	Length of Section. Feet. (3)	Number of Joints. (4)	Pressure Range. Lb. per Sq. In. (5)	Last Joint Made. Date. (6)	Time between making last Joint and turning on water. Hours. (7)	Duration of Test. Hours. (8)	Leakage per Joint. g. p. d. (9)	Leakage per foot of Joint. g. p. d. (10)
	Force Main No. 1				1921				
	Sec. Test								
12	1 — 1	2 340	196	0–100	Oct.	36	16.5	.0359	.24
	— 2	....	....	20–100	Oct.	64	5.5	(.0898)	(.61)*a*
	— 3	....	....	0–138	Oct.	72	20.7	.0359	.24
	— 4	....	....	125–140	Oct.	94	21.6	.0224	.15
	— 5	....	....	125–160	Oct.	115	6.5	.2064	1.4
12	2 — 1	2 328	208	110–135	Nov.	26	24.0	(.4308)	(2.92)*b*
12	3 — 1	2 060	180	0–135	Dec.	20	24.0	(.7181)	(4.88)*c*
12	4 — 1	4 153	357	0–100	Dec.	24	7.0	.01	.27
					1922				
12	5 — 1	4 040	346	0– 65	May	30	50.5	.1967	1.34
12	6 — 1	1 752	148	0– 65	May	40	45.0	.02	.14
Weighted average per ft. of joint, omitting results in parentheses								=	0.59 g. p. d.
	Force Main No. 2				1922				
10	1 — 1	1 865	164	0–105	Aug.	72	3.0	.0015	.01
	1 — 2	....	....	0–105	Aug.	75	54.0	.018	.15
	1 & 2 – 1	12 416	1 222	35–105	Aug.	171	21.4	(.58)	(4.67)*d*
	1, 2 & 3 – 1	17 455	1 700	0–110	Aug.	243	48.2	(.78)	(6.28)*e*
10 & 12	Complete	22 210	2 115	105–225	Dec.	384	117.5	.0479	0.38*f*
Being weighted average, per ft. of joint								=	0.38 g. p. d.

a Estimated that half of this leaked through a stuffing-box.
b Including leak around an old corporation cock.
c Including leak through blow-hole in defective bell of pipe.
d Including leak in cracked pipe.
e Including leak through stuffing-boxes of gate valves.
f After cracked pipe was replaced and gate stems packed.

SOME COSTS OF LEAD SUBSTITUTES IN PIPE JOINTS.

BY VERNON F. WEST.*

[*Read at Annual Meeting January 9, 1923.*]

Since 1914 with the beginning of the World War and the attendant increase in prices of all commodities entering into the operation and construction of water works, the management of these properties whether publicly or privately owned, have been attempting to adjust themselves to the new operating conditions. How long the present conditions will prevail is idle to prophesy, but they are ever present with us and are the conditions with which we have to contend. To overcome these conditions, moderate rate increases have been made, additional business on existing lines has been secured, operating economies practiced and new construction methods adopted.

In the same period of years, New England has been experiencing both an industrial and residential growth. In the war period the industrial growth, due to the demand for manufactured articles for war purposes, caused a period of business expansion heretofore unwitnessed. From the operative standpoint, with the exception of a relatively small capital outlay for additional pumping capacity, the new capital expenditures should have been relatively low as most of the war work was financed directly or indirectly by the Government. Since the war period we have seen an unprecedented demand for homes and the development of suburban areas. How to keep pace with this demand for extensions in these newly built-up sections has caused many of us to sit up nights and wonder how the work could be reasonably done without undue burden on the rate payer. In New England particularly this situation is typical, for we have here a large mileage of improved roads per square mile of area. Modern transportation and good roads bring these suburban areas within easy access of the thickly settled districts and are becoming more and more attractive as residential centers for those who have moderate incomes.

In view of the above conditions, the writer in 1919 began to investigate the feasibility of using lead substitutes for joint material to see if some substantial saving could not be realized in the cost of new extensions without jeopardizing the character of the work. We commenced by making up joints in the pipe yard with various lead substitutes and submitting them to various tests. In 1920 and 1921 we used both lead and lead substitutes on the new work, reserving the lead substitutes for the outlying sections where we could leave our ditches open and watch the results

* George F. West & Son, Portland, Me.

of the use of these substitutes. In all cases we found a material saving in costs over the use of lead for joints, but found that we did use more of the lead substitutes than claimed normal by the manufacturer. After three years' use of it in pipe laying up to 16 in., we find that joint material used will closely conform to the following table:

JOINT MATERIAL REQUIRED.

Size.	Lead Lb.	Lead Substitutes Lb. Mfg'rs Schedule.	Lead Substitutes Lb. Actual.
6 in.	10.25	2.75	2.85
8 ,,	13.25	3.50	3.50
10 ,,	16.00	4.25	7.10
12 ,,	19.00	5.00	8.00
16 ,,	30.00	8.00	10.50

We have found this to be the actual result in the field, and is further confirmed by carefully prepared joints in the shop.

This past year in Maine and in work with which I was connected, over 62 000 ft. of cast-iron pipe was laid where lead substitute for joint material was used. At two places we kept accurate account of the work performed by the joint crew so as to form some definite comparison of our cost with lead joints. This we did by having one man on the lead furnace keep a tally book of the joints made daily and the hours joint crew worked. This was carefully checked by the foreman on the job as to its accuracy and then turned over to the superintendent. From that data, using a typical crew to perform the same amount of work with lead as joint material, at rates of wages actually paid by us in 1922, I have estimated the cost of the work making lead joints in place of the lead substitute joints actually made.

16 IN. CAST IRON PIPE.

(1) Leadite Crew.	Daily Cost.	(2) Lead Crew.	Daily Cost
1 Furnace man	$3.60	1 Furnace man	$3.60
2 Yarners @ $4.00	8.00	2 Yarners @ $4.00	8.00
1 Joint man	4.00	1 Joint man	4.00
339.1 lb. leadite @ $0.10	33.91	2 Calkers @ $5.00	10.00
		2 Bell hole diggers @ $3.60	7.20
		969 lb. lead @ $0.07	67.83
Total daily cost of joint crew and leadite	$49.51	Total daily cost of joint crew and lead	$100.63

Total number joints ran including gates, hydrants and specials	1 552
Total days work, 9 hours, performed	48
Average joints ran per day	32.3

Difference per day between (1) and (2) is $51.12 saving in favor of using a lead substitute. Taking the whole number of days joint crew worked on this line, or 48 days, we have a total saving of $1,807.20.

12 in. Cast Iron Pipe.

(1) Leadite Crew.	Daily Cost.	(2) Lead Crew.	Daily Cost.
1 Furnace man	$3.60	1 Furnace man	$3.60
1 Yarner	4.00	1 Yarner	4.00
1 Joint man	4.00	1 Calker	5.00
350.4 lb. leadite @ $0.10	35.04	1 Bell hole digger	3.60
		832.2 lb. lead @ $0.07	58.25
Total daily cost	$46.64	Total daily cost	$74.45

Total number joints ran including gates, hydrants and specials	789
Total days work, 9 hours, performed	18
Average joints ran per days	43.8

Difference a day between (1) and (2) is $27.81 saving in favor of using a lead substitute. Taking the whole number of days joint crew worked on this line, or 18 days, we have a saving of $447.50.

10 in. Cast Iron Pipe.

(1) Leadite Crew.	Daily Cost.	(2) Lead Crew.	Daily Cost.
1 Furnace man	$3.60	1 Furnace man	$3.60
1 Yarner	4.00	1 Yarner	4.00
1 Joint man	4.00	1 Joint man	4.00
319.5 lb. leadite @ $0.10	31.95	1 Calker	5.00
		1 Bell hole digger	3.60
		720 lb. lead @ $0.07	50.40
Total daily cost	$43.55	Total daily cost	$70.60

Average work performed per day .... 45 joints

Average daily difference between (1) and (2) is $27.05 saving in favor of using a lead substitute.

8 in. and 6 in. Cast Iron Pipe.

(1) Leadite Crew.	Daily Cost. 8 in.	Daily Cost. 6 in.	(2) Lead Crew.	Daily Cost. 8 in.	Daily Cost. 6 in.
1 Furnace man	$3.60	$3.60	1 Furnace man	$3.60	$3.60
1 Yarner	4.00	4.00	1 Yarner	4.00	4.00
1 Joint man	4.00	4.00	1 Joint man	4.00	4.00
Leadite @ $0.10:			1 Calker	5.00	5.00
8-in. 175 lb.	17.50		1 Bell hole digger	3.60	3.60
6-in. 142.5 lb.		14.25	Leadite @ $0.07:		
			8 in. 662.5 lb.	46.38	
			6-in. 512.5 lb.		35.88
Total daily cost	$29.10	$25.85	Total daily cost	$66.58	$56.08

Average joints ran per day 50

Difference a day between (1) and (2) is respectively $37.48 and $30.73 in an 8 in. and 6 in. joint, saving by use of a lead substitute.

Summary.

Relative Cost of Lead and Leadite Joints.

Size.	Average Joints made per Day.	Cost per Day. Crew and Material. Lead.	Leadite.	Cost per Joint. Lead.	Leadite.	Saving per Joint.
6 in.	50	\$56.08	\$25.85	\$1.121	\$0.517	\$0.604
8 ,,	50	66.58	29.10	1.331	.582	.749
10 ,,	45	70.60	43.55	1.57	.968	.602
12 ,,	43.8	74.45	46.64	1.70	1.064	.636
16 ,,	32.3	100.63	49.51	3.116	1.532	1.584

While the statement of lead costs are estimates, they are based on the writer's experience doing similar work with lead as joint material in 1920 and 1921. Furthermore, a check of the 16 in. and 12 in. lines was obtained in the following manner. In the fall of 1921, we were contemplating the purchase of a water works system in the eastern part of Maine and had Metcalf & Eddy of Boston do the preliminary engineering work. In estimating the cost of new lines necessary, one of which was the 16 in. and 12 in. line mentioned above, they said in part as follows:

"This estimate is based upon the following assumption,—

(1) That cast iron pipe can be purchased and delivered at the site of the work for \$40 per net ton.

(2) That common labor will not cost over 30c. an hour.

(3) That conditions encountered in laying the main pipes will be so favorable that the cost will be comparatively low or perhaps that trenching machine will be used for a great part of this work.

(4) That no ledge is likely to be encountered in this portion and that this section can be laid either in the shoulder of the highway outside the concrete paving or in a private right of way without appreciable additional cost. . . ."

In the Spring it was decided to go ahead with this work, purchases were made and work started July 10. How close conditions approached those as made up in the original estimates were as follows:

(1) Pipe cost on the work \$44.00 a net ton in place of \$40.00 estimated.

(2) Common labor did cost 40c. an hour in place of 30c. estimated.

(3) A steam shovel was used whenever possible or about one third the distance.

(4) About 500 feet of ledge was encountered and payment made to the State Highway Department of about \$1 200 for damage to shoulder of concrete road.

Even with the additional costs as above enumerated, the work recently completed was done within the original estimate. As shown before, the estimated direct saving on the use of lead substitute joint material was \$2 254.70. The other indirect labor saving in this case was several thousand dollars as the 6 ft. deep trench was in gravel and would cave badly should bell holes be dug without bracing. Then again, the months of

July and August were wet in this part of the state, requiring more care in keeping the joints dry before pouring should lead have been used.

At various times I have been in correspondence with other leadite users and find they also have experienced marked savings over using lead for joints. It will be no breach of confidence if I quote this instance:

"You may remember I made an estimate of the comparative cost of lead and leadite when we made two lead joints on the check valves,—

Cost of Leadite Joint.

2 lb. gasket @ $0.29	$0.58
32 lb. leadite @ $0.11	3.52
Labor 3 men, 10 min	.32
Total cost of joint	$4.42

Cost of Lead Joint.

2 lb. gasket @ $0.29	$0.58
205 lb. lead @ $0.07	14.35
Labor 3 men, 1 hr. 40 min	3.13
Total cost of joint	$18.06"

A number of other advantages can be mentioned in the use of lead substitutes over lead, namely:

(1) Requires less heat to melt.
(2) Greater ease in handling as it is so much lighter than lead.
(3) Temperature changes do not start a joint as with lead.
(4) Vibration due to train or trucks does not start a joint as with lead.
(5) Less risk in handling and greater ease in making joints in difficult places.

All these facts result in a saving that cannot be measured readily in dollars and cents, but are actually real when a job is completed and the final cost is found.

In conclusion I may state that it is important that all economies possible must be adopted by water-works managers consistent with good engineering practice, whether it be by use of higher efficiency machinery, labor-saving tools or substitute materials which will perform the same service but at lower cost. In recent years, as illustrating this, we have seen Diesel engines, high-duty centrifugal pumps, trenching machinery, backfilling machines and the use of lead substitutes. Only with the adoption of the above principles can the cost of new work, with the present price of materials and labor, be held at a reasonable level. Unless this practice is followed, water rates must be increasingly higher as the investment in the new construction outweighs the investment in the pre-war plant.

Joint Discussion.

President Barbour. This paper of Mr. West's offers a very interesting sequel to Mr. Wheeler's paper.

Let me, just as a starter of this discussion, point out that Mr. West estimates a lead joint of twelve inches to cost $1.70, and if made of leadite $1.06, as opposed to Mr. Wheeler's figure of 46 cents. Let me also point out that Mr. Wheeler's leakage, as near as I could catch it, was something like 50 to 60 gal. per inch mile per day. I know that in Columbus, Mr. Gregory some years ago specified 500 gal. per inch mile per day, and I remember that in Akron actual leakage was about one hundred gallons per inch mile. I just make these remarks to establish the point of Mr. Wheeler's paper.

These two interesting papers are now open for discussion.

Mr. Leonard Metcalf.* I was very much interested in both of these admirable papers. One question is suggested by Mr. Wheeler's paper. I take it from his statement that the quantities were measured by a $\frac{5}{8}$ in. meter. Now, with a very small quantity of water flowing through the pipe, what was the probable per centage of error in the registration of the meter? In one of the cases he cited the figure given might have involved a flow of two gallons a minute. Of course that is a very small quantity of water. I wondered whether he had made any figures to see how a reasonable percentage of error in the registration of the meter would have affected the quantities of leakage which he cited.

Mr. Wheeler. Mr. Metcalf's question is most pertinent. Unfortunately we have no details about the range of flows that were used in testing the meter. Mr. Cashman — who is here — tells me that it was tested by the superintendent, and that, within the range of discharge orifices or quantities which were used, the registration was found to be correct.

Referring specifically to the test for force-main No. 2 *complete,* the leakage for the entire main registered at the rate of 0.38 g. p. d. per ft. of joint, which for the 2 115 joints of both 10-in. and 12-in. pipe, having a total-joint length of about 6 400 ft., amounted to 2 432 gal. per day, or 1.69 g. p. m. That is $\frac{2}{3}$ more than the lowest *normal* test-flow limit of 1 g. p. m., for which the Standard Meter Specifications of this Association require that the registration on the dial of a $\frac{5}{8}$-in. meter shall indicate not less than 98 per cent., nor more than 102 per cent. of the water passed through the meter.

Force-main No. 1 — as replaced in sections while the rest of the main was in use — could not be tested as a whole. The sections were therefore tested separately as the work progressed, and these sections ranged from 1 752 to 4 153 ft. long and had respectively from 148 to 357 joints each. Referring to the Table, it appears that of the two longer

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* Of Metcalf & Eddy, Boston, Mass.

sections (4) and (5), the leakage of section No. 4 was registered at the rate of 0.24 gal. per min., which is 96 per cent. of the lowest *minimum* test flow of $\frac{1}{4}$ gal. per min. at which, under our Standard Specifications for a $\frac{5}{8}$-in. meter, not less than 90 per cent. of the actual flow is required to be recorded; and similarly the leakage registered for section No. 5 was at the rate of 1.14 gal. per min., or 14 per cent. more than the lowest *normal* test flow of 1 g. p. m., at which not less than 98 per cent. of the actual flow is required under the specifications.

Of the other tests of force-main No. 1, only the fifth test of section No. 1 showed a recorded flow equal to the lowest *minimum* test flow under the specifications. This test was under the highest pressure on main No. 1, and the flow recorded for this test was at the rate of 0.67 g. p. m., which is $\frac{2}{3}$ times the *minimum* test flow, at which a registration of not less than 90 per cent. of the actual flow is required under the meter specifications.

The flows recorded for the three other tests of section No. 1 and for the test of section No. 6 (the only other test not affected by other leakage than at joints) ranged from about one-half to one-quarter only of the *minimum* test flow required under the specifications; and it therefore seems reasonably certain, if not logically demonstrable, that the actual leakage per foot of joint in those tests recording such low flows was less than in cases where the higher registrations were made.

Mr. West. May I ask you, — in making these cement pad joints, you say it took about twenty-five minutes for a man to make a joint, — did I get that correct?

Mr. Wheeler. Yes, that is substantially correct, — the work of the calker.

Mr. West. In other words, a man would make a little better than two joints an hour.

Mr. Wheeler. Apparently that is so.

Mr. West. It seems to me offhand that on the 9-hour day he would probably get 25 or 30 joints at the least. Now, where we use a steam shovel with a crew of 40 or 50 men, we set anywhere from 400 ft. a day in the larger-size pipe up to 1 000 ft. in the smaller-size pipe, and it would mean doubling up your joint crew to keep up with that work and not hold up the other end of the crew.

Mr. Wheeler. Mr. West's comment is suggestive. As I have stated, one mixer took care of three cement joint calkers, and occasionally had time to do other things, like covering the joints of the pipe. If I recollect rightly, — and I hope the members of the Association will fortify themselves by reference to the papers which I have mentioned, — my impression is that in some of the California practice, one mixer waited upon two calkers, indicating perhaps less time spent in calking. It also may be of interest to recall that Mr. Pracy contributed to the subject in two of the papers which I mentioned, and that in his discussion of Mr. Clark's

earlier paper, he describes some experiences of the Spring Valley Water Company in which stiff wet cement was used in making the joints, — the cement being worked by hand, and tramped by hand with a calking iron, thus producing a joint made with no hammer calking whatever. This joint he compared favorably with the dryer or moist-mixed joint, hand-rammed and hammer-calked, which though taking twice as long to make, and a good joint, was not better than the others. In his later paper describing other work on which he had since engaged, using the calking process with the dryer-mixed cement, he makes no reference to his prior experience and discussion concerning the hand-made, wetter-cement joint, but commends highly the dry-mixed, hammer-calked joint; and which he found gave less leakage than noted in the earlier processes which he had discussed.

Mr. Metcalf. Referring to the experiments to which reference has been made in California. That work was going on in the west when I was there. Mr. Lippincott told me that he made the mortar of a consistency so that when he lifted the bell in his hand and dropped it a couple of feet the dry pieces would drop out and scatter, — not as wet as used in concrete ordinarily.

It is my recollection that they calked it there without a hammer, did they not?

Mr. Wheeler. Yes.

Mr. Metcalf. That they rammed it with the hand, but without the use of a $3\frac{1}{2}$ lb. hammer. And the amount of work done per man was substantially greater than where the hammer has to be used.

Mr. Thomas H. Wiggin.* There is a large amount of experience showing that cement, concrete and mortar reduces in leakage very greatly in the course of time. It would be very interesting to know whether these pipes show that same reduction as is common with reinforced concrete pipe, and all kinds of masonry having Portland cement.

Mr. Stephen H. Taylor.† Has any experiment been made to show the flexibility of the cement joint as compared with lead or leadite?

Mr. Percy R. Sanders.‡ We have had in Concord, as Mr. Wheeler said, a line of about 3 000 ft. of uncoated 6-in. cast-iron pipe which must have been laid as far back as 1872. In 1907 and 1910, we had occasion to replace a portion of this pipe and in taking it out, it would break beyond the joint, there being no flexibility at all to the joint.

It looked to me as if the joint was made by first ramming in some cement, then driving yarn into the cement, and then the joint was filled with more cement to end of bell.

We have at present about 400 ft. of this class of pipe with cement joints in service. It has never given us any trouble to my knowledge. I had forgotten that we had it until Mr. Wheeler called me up and asked me about it.

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* Scarsdale, N. Y.
† Superintendent, Water Works, New Bedford, Mass.
‡ President-Elect — Superintendent, Water Works, Concord, N. H.

Mr. George H. Finneran.* We found in our tests of cement that the pipe would break between the joints; the joints held to the last. In fact, the pipe broke in the bell. The joints did not move in the least degree.

Mr. John Doyle.† Have you had any experience with cement being used with a grout, taking about the same mixture as leadite and pouring it as you would pour your lead or leadite?

Mr. Wheeler. I would refer to some of the papers to which reference has been made for information on that. I think it was stated that the mortar used should be not fluid enough to flow, but stiff enough to be placed by hand, and forced in by hand pressure and by the aid of a calking iron.

Mr. W. C. Hawley‡ (*by letter*). During the early part of last season our company laid an 8-in. cast-iron-pipe line with leadite joints to supply a single large consumer. There was a delay incident to the securing of a right of way for a part of the line and advantage was taken of the opportunity presented to make some tests of the line.

The pressures ranged from 30 lb. to 70 lb. per sq. in. There were no valves or special castings in this pipe line, the first test covering 131 lengths of the total length of 1 572 ft. The other three tests were of the line made of 185 lengths of the total length of 2 220 ft.

The test was made by using a $\frac{5}{8}$-in. meter on a short by-pass around the valve close to the connection to the supply main. The progressive decrease in the amount of leakage will be noted. The final test for the 2 220 ft. length showed a leakage at the rate of less than 3 gal. per hour. It was difficult to get a satisfactory registration of the meter below this rate.

It is probable that much of the leakage shown in the early tests was due to air in the pipe finding its way through the joints, as there was no hydrant or other connection through which the air could be blown. The pipe had been tested in open trench with no evidence of leakage.

The following table shows the details of these tests:

Test No.	From (1922)	To (1922)	Time Hr.Min.	Registration. Gal.	No. of Joints.	Length Feet.	Leakage per Day Gals.		
							Per Mile.	Per Inch-Mile.	Per 1 000 Feet.
1	3.20 P.M. 6/10	3.15 P.M. 6/12	47–55	1 485	131	1 572	2 500	313	2 418
2	3.15 P.M. 6/12	9.45 A.M. 6/13	18–30	537	131	1 572	2 340	292	2 267
3	4.55 P.M. 6/19	4.00 P.M. 6/20	23–05	137	185	2 220	1 185	148	1 146
4	12.00 M. 6/23	3.55 P.M. 6/24	27–55	84.7	185	2 220	806	101	780
5	11.00 A.M. 7/3	9.00 A.M. 7/7	94–00	207.4	185	2 220	530	66	512

* Superintendent, Water Service, Boston, Mass.

† Foreman Water Department, Worcester, Mass.

‡ Chief Engineer and Manager, Pennsylvania Water Co.

SOME DATA ON PIPE JOINTING COMPOUNDS.

BY GEORGE H. FINNERAN.*

[*January 9, 1923.*]

It is safe to say that the three compounds known as leadite, lead-hydrotite, and metallium are generally known by water works men and regarded by them as practical substitutes for lead as a pipe-jointing material; and that if the directions of the manufacturers are strictly followed, a water-tight, and so far as we know, a durable joint will result.

The officials of the Water Service of Boston had faith enough in leadite to use it for a jointing material in a line of 10-in. pipe laid in 1910. That line has never caused any trouble and an examination of several of the joints two years ago showed them to be sound and tight and entirely satisfactory so far as appearances indicate. Deflection tests have been made by the writer of short spans of pipe jointed with leadite, lead-hydrotite, and metallium, respectively, and the results secured gave ample assurance that a line of pipe in which any of these three compounds were used would withstand a considerable settlement without failure of the joints. As a matter of fact I found that the pipe itself broke before the joints showed any leakage. This may or may not be a desirable characteristic. It may be that some of us would rather receive the warning that a leaky joint gives. If so, other tests showed that a lead joint will leak during a deflection test and increase as the process goes on; and the pipe will not break before the joints fail, or to put it another way, the joints will fail before the pipe breaks. I am inclined to the conclusion on this particular point that the sulphur and sand compounds are more tenacious than lead.

I have also tested leadite for electrical conductivity and found that current will not flow on a line of pipe made up with leadite joints of recent date, but will flow on a line laid in the ground for some time. I found in the latter case that the leadite itself had not changed from a non-conductor to a conductor, but that it had acquired a film of what appeared to be iron-oxide on its face and it was through this film that the current passed from one pipe to another.

Occasionally one hears that joints made of this material expand as they cool and advance in age. As a crude way of determining this point we poured some leadite into a bottle about two years ago, filling the same completely. We have observed it from time to time but as yet there is not the slightest indication of an expansive movement in the material.

In Boston we use these joint compounds almost entirely in wet work. I think that is a more severe test than to use them in dry work. It is not

* Superintendent, Water Service, City of Boston.

often that gates are absolutely tight. Rather is it that they leak, and making up a joint under such conditions is the acid test for joint-making material. A few years ago we laid about 1 000 feet of 12-in. pipe on a temporary bridge structure over the Neponset River. We used leadite in the joints. Owing to an excessively thick coating of tar on some of the pipes, several of the joints leaked quite freely after the water was let on, but in time all joints became tight and despite the vibration to which the line was subjected, due to traffic over the bridge, including heavy trolley cars, auto trucks, and occasionally a severe bump from the vessel passing through the draw, the joints remained tight.

We were desirous, however, of having some knowledge based upon scientific tests as to the qualities of tensile strength, compression, and water absorption, possessed by these compounds, so we arranged with the Massachusetts Institute of Technology, Department of Mechanical Engineering, to conduct a series of experiments to determine the facts.

Specimens were made up under the personal direction of the writer in the forms of briquettes, cubes, and bricks, — three sets of each, one of leadite, one of lead-hydrotite, and one of metallium. They were not labelled with the names of the compounds but were given serial numbers as follows: Leadite specimens were marked 1. Lead-hydrotite specimens were marked 2. Metallium specimens were marked 3. The tests were conducted by Irving H. Cowdrey, at the Testing Materials Laboratory of the Mass. Inst. of Tech. and following is his report on the same:

Report of Tests on Pipe Joint Cement.

Samples furnished by G. H. Finneran for the Public Works Department of the City of Boston.

Tests made by Irving H. Cowdrey at the Testing Materials Laboratory of the Mass. Inst. of Tech.

The specimens submitted were in one of three forms namely:

1. Two inch cubes for testing under compressive stress.

2. Briquettes of the form described in the Standards of the A. S. T. M., C-9-17, Art. 51, for testing under tensile stress.

3. Samples in the form of and approximate dimensions of common building bricks for determination of the water absorption.

Three sets of samples were submitted, each set being marked with a serial number, 1, 2, or 3 respectively. A set consisted of nine samples for tension, nine samples for compression, and three samples for absorption.

The tests for tension and compression were made at the following periods from the time of manufacture, approximately; namely 24 hours, 7 days and 14 days. The absorption was determined by placing the bricks after weighing, in water about $\frac{1}{2}$ in. in depth and observing the weight at the end of 30 minutes and 48 hours.

The results appear in the following tabulation.

Tensile Tests.

Series.		Strength in pounds per sq. in. at end of 24 hours.	7 days.	14 days.	Average of all tests.
1		610	510	630	
		660	635	505	
		510	595	670	
	Av.	593	580	602	592
2		630	630	620	
		590	650	495	
		610	685	550	
	Av.	610	655	555	607
3		510	640	670	
		530	550	790	
		540	650	620	
	Av.	527	613	693	611

Compression Tests.

Series.		Strength in pounds per sq. in. at end of 24 hours.	7 days.	14 days.	
1		4 090	4 380	4 760	
		4 810	4 500	5 320	
		4 840	3 700	4 220	
	Av.	4 580	4 193	4 766	4 516
2		3 970	4 170	2 960	
		3 990	4 500	4 210	
		3 970	4 500	3 830	
	Av.	3 970	4 390	3 666	4 009
3		4 800	5 380	4 120	
		3 475	4 000	3 440	
		3 472	3 510	3 900	
	Av.	3 916	4 297	3 820	4 011

Absorption Tests.

Series.	Weight in grams at end of Initial.	30 min.	48 hours.
1	2 380	2 382	2 385
	2 347	2 348	2 348
	2 335	2 335	2 337
2	2 283	2 285	2 287
	2 360	2 361	2 365
	2 335	2 336	2 337
3	2,284	2 284	2 285
	2 245	2 247	2 250
	2 303	2 303	2 305

CONCLUSIONS.

A. The time factor is of little or no significance in its effect on the strength of these cements.

Tensile Strengths. — Series 1. It will be noted that the lowest value appears in the tests made at the end of 14 days, while next to the largest result is for a 24-hour test. There is no marked difference between the average of all three periods.

Series 2. The conditions in this set are identical with those outlined above.

Series 3. There would seem to be a more regular behavior here than with the other two series, in that there is a continual increase in the values shown by the averages as the age of the sample increases. In the opinion of the writer, however, this is purely a coincidence since no such regularity appears in the compressive strengths.

Compressive Strengths. — Vagaries very similar to those noted in the tensile strengths also appear in these results.

B. The material under observation are practically non-absorptive under the conditions imposed.

Note: The greatest absorption was less than ¼ of 1 per cent. The extremely slight increase in weight recorded would indicate that the water taken up was merely that which was held in the very small cavities existing at the surface of the samples.

C. In the opinion of the writer there is no noticeable difference in the properties of these three series of samples.

Respectfully submitted Sept. 28, 1920,

(Signed) IRVING H. COWDREY.

The statement of Professor Cowdrey in his report that there is no noticeable difference in the properties of these three compounds covers only the period in which they were under his observation. It may be that if they were submerged in water or buried in soils of varying character, or subjected to heat and cold, for a number of years, that noticeable differences in the properties of each might be apparent; or possibly not. That can be determined only by time. As with some things in this world it probably will be a case of the survival of the fittest.

AN IDEAL.

(RE MUNICIPAL WATER WORKS ADMINISTRATION)

BY ALFRED R. HATHAWAY.*

[*December 12, 1922.*]

Without consulting the dictionary I believe that all of us have in our minds a similar understanding of what the term *Ideal* is intended to convey in its best and practical sense, and that we would feel deprived of the most valuable incentive to endeavor that we mortals possess if we could not hold before us always some sort of vision of the desirable goal or end to be ultimately attained, if possible.

At the same time we can certainly sympathize fully with the three boys and their individual misconceptions in the following story.

It is told of a certain prominent teacher who at one time was scheduled to address another school nearby, that she sought from one of her boy friends some advance suggestion as to just what sort of subject she might select. The boy, in response, suggested that she speak upon any subject except that of "Ideals," as he had become tired of hearing that talked about so much! The next day, wondering if the pupils in her school actually understood what that subject meant, she asked each one to write on a sheet of paper their individual understanding of the definition required by the question "What Is An Ideal?" and hand it in.

But she told them that, if they felt doubtful in their minds, they might consult the dictionary and then put the meaning in their own words. All but three boys followed the dictionary method, and these boys gave the following answers; — one boy wrote "An Ideal is what the heathens worship in foreign lands!"; the second boy wrote "It is what you can never be or do!"; while the third boy's answer was "It's a sewing machine, and my father sells 'em!"

Now I'm not so dead sure that the second boy may have been so far away from the truth as it may have appeared. And yet, as we are all trying to follow faithfully our different paths of duty, I am sure there is not one of us who does not keep in mind a vision of something far better than the present experiences and attainments.

All of which leads me to discuss a few "brass tacks" concerning the ownership and administration of municipal water works, past, present, and future, and comprehending whatever we may conclude to be "*An Ideal*" in this special field of public service.

* Water Registrar, Springfield, Mass.

As many of you already know my views on this subject, much of the following may appear and will be largely repetition of statements and opinions I have made and quoted before, and for such I crave your indulgence at the outset.

What is the fundamental relationship of a water works to both the town or the municipality owning and operating it and to the public served?

We all know that a water-works enterprise in the far earlier years was almost invariably a privately-owned business and operated for profit to its owners, and later became classed as a " Public Utility " along with other similar enterprises, such as gas and electric plants, telephone companies, railroads, etc.

Then the accounting, financing, rate making, and methods of public service by all such privately-owned " Public Utilities " gradually became placed under the control and regulation of state commissions, known as Public Utility Commissions, Public Service Commissions, Railroad Commissions, and the like, for the better mutual protection of the interests of the stockholders and of the public served. This control is now exercised by some form of state commission in nearly every state in this country, and these regulating commissions are handing down many authoritative opinions concerning the methods of operation and service by such privately-owned utilities, which opinions by analogy, and often directly, are very pertinent to the conduct of the municipally-owned utilities of the present day. In his paper at the New Bedford convention Mr. King very truly stated that " The supplying of water to a municipality is *not* one of the original functions of town government. It is one of the necessities occasioned by our advance in civilization, . . . better known as a Public Utility, which the municipality has been allowed to finance principally for the preservation of public health and incidentally for fire protection and manufacturing purposes, but not for the purpose of making a profit. As a public utility it should be managed independently of the general functions of municipal operations."

I quote his remarks here as particularly pertinent to the progression from the privately-owned to the municipally-owned water-works utility.

I wish for a moment to call your attention to a converse thought to the foregoing remarks about the privately-owned utilities of years ago.

Not being present in the body during the past ages I cannot personally vouch for the fact that in those earlier days such private enterprises as stock corporations for the ownership and operation for profit of Police Protection, Public Schools, Streets and Highways Companies, Fire Companies, Public Park Companies, and the like, *were entirely unknown;* but I unhesitatingly accept such statement as fact, as we cannot conceive of

such enterprises ever entering into the class of "public utilities" under private ownership.

From the beginning I believe such enterprises as these sprang from a community of interests being formed by the needs of the many individuals in the aggregate going to make up the village and town of those earlier days and of the growing city of later years.

By mutual agreement of the governed and consolidation of the common interests into what we term "governmental bodies" such public enterprises were undertaken and placed under control of *governmental departments* (so-called), and were financed by means of assessments upon the property of all members benefited, which assessments we call *taxes*.

We have then two distinct classes of public enterprises in our minds: — *first* — those which are universally called "*public utilities*" by all the competent authorities, and which may be owned and operated by either a private corporation or by a town or municipal corporation; *second* — those which are and always were called "*departments*" or functional divisions of town or municipal government.

Every thinking person knows and believes that the first class should be financed by the assessments of equitable "rates" upon each user or consumer of the service rendered, in accordance with the benefit derived from that service; while the expenses of the second class should always be met by "tax assessments" upon the property to be benefited.

Now then:— under the foregoing generally acknowledged fundamental divisions of administration of the two classes of public enterprises, the failure of town and municipal authorities to keep in mind such fundamental divisions has been the cause of the many failures of municipal ownership of Public Utilities; such failures are in process at the present time, and will continue until some authority above the usual local political governing bodies takes over and exercises the proper and needful regulation, whereby the administration of the Public Utilities becomes and continues to be a "*business*" administration instead of a "*political*" one.

In this connection your attention is invited to the following from the September, 1920, issue of "The American City" magazine:

"Every municipal water department should be conducted as a separate 'administrative entity' and should be entirely separated from the general city government. Such a policy necessitates the conferring of broad and extensive powers upon the administrative body, such as are usually exercised by a private corporation engaged in supplying water for public uses.

"The division of authority between the body administering the water plant and the officers conducting the general city government has not proved workable and does not contribute to efficiency in either department. The business of supplying water when conducted by a municipality is first and always only a business and should be managed and conducted solely as a business, not for the purpose of obtaining the largest possible revenue, but to attain the greatest possible efficiency and to supply, at a moderate charge, all public requirements. . . . The persons chosen for constructing and operating a municipal water plant should be chosen for their technical knowledge of the particular enterprise which is to be committed to their charge.

"Knowledge of the broader questions of municipal government in no way qualifies individuals with the technical knowledge to successfully operate a water-works system. An attempt to operate the water system as a distinct part or branch of a general scheme of municipal government, whether that government be conducted by a political body elected in the manner generally prevailing throughout the United States, or by commissioners under some modification of the city management plan, will usually fail of achieving the efficiency which otherwise would be obtainable, for the reason that general city officers, or the officers conducting the general city government, are chosen from time to time upon issues involving questions of ethics and morality and the general policy of the government which have no relation whatever to the business of managing the water system. . . . From the very nature and fundamentals of the usual city administrative body, the officers chosen by the people to conduct the general city government rarely possess technical knowledge or experience in any given line of business. This results in loss to those branches of the municipal government which are purely 'business' in their nature."

The foregoing would seem to sufficiently answer my question as to the fundamental relationship of a water works (or any other similar public utility) to the public served and to the town or municipality owning and operating it. Many such authoritative opinions are available, which, when summarized briefly, state in effect that the relation of the municipally-owned utility is exactly the same as that of a privately-owned utility under an efficient business administration.

There arises at this point the logical question of what is understood by and included under an efficient business administration of both privately owned and municipally-owned public utilities?

We hear much, nowadays especially, of the privately-owned utilities adopting all manner of modern devices and approved business practices, both in proper accounting and public service (as prescribed by the various state-regulating commissions), in order that the most economical and efficient administration of such utilities may result in adequate dividends to the stockholders.

If such were not the case we would hear of many utilities going out of business. As I have stated at other times and in other places, I cannot see why, when such a public utility is taken over or established under a municipal ownership and operation, the governmental owners immediately proceed to omit some of these very needful practices (such as proper uniform accounting, including the provision for depreciation, the insuring of all earnings and revenues accruing to the utility from municipal uses as well as from private uses, the payments of all expenses borne by city departments and other officials on account of the utility, payment of city taxes, etc.), with the result that there is no means of knowing how the utility stands financially as a supposed self-supporting enterprise, and no comparison can be made with a similar privately-owned enterprise. In my 1914 annual report to the Springfield Board of Water Commissioners I stated that "When the water works receives all its just earnings in cash or its equivalent — in the same manner and to the same extent as in the

case of a privately-owned public utility — and when it pays all expenses properly chargeable to such a public utility; then, and not until then, can an adequate financial statement be made, showing the true relation the water works bears to its owner, the municipality, as a ' public service enterprise ' or investment."

Since that time I have seen no reason for changing my opinion, but rather each year become more strongly confirmed in same by reading the similar opinions of recognized authorities on this subject, to whom we look for guidance in our search for right practices.

In quoting some of my own opinions in this paper I assure you it is not done in any egotistical sense at all, but rather as an easier way for me to place before you my personal feelings in the matter and to save the time of trying to express such opinion in another way.

For this purpose also I shall offer you certain opinions of *real authorities* (or some of them) in support of the principal features of the subject as we most of us must believe, and quoting some of them more or less at length for a better possible future reference if wanted. Here are a few of such taken from my files and which should not and, in my opinion, cannot be gainsaid by thinking persons.

Extract from letter of Mr. William J. Hagenah of Chicago (one of the leading public utility engineers and statisticians of this country) in commenting on the Springfield Water Commissioners' Report for 1918:

" I note with much interest the position taken by your board as set forth on pages 10 and 11 of the report, wherein it is urged that the city should compensate the water works for the services which it received. This position is so eminently sound from an economic and business standpoint that it does not admit of argument, and one naturally wonders why cities refrain from treating their utilities in a business-like manner. It is only by following this course that those who are giving their best efforts to the management of such properties can show the public the true results of their services. That certain departments of the city should make a heavy and expensive demand on the water-works property without meeting the costs which they incur is unfair to the water works and would not be tolerated in any other line of business."

Recent legal decisions from " Public Works " magazine of October, 1922.

(*a*) " The Wisconsin Commission is of the opinion that the electric consumers of a municipal plant should not be required to carry the burden of the water department. Each utility should stand upon its own feet. The larger portion of the operating expenses of the plants is chargeable directly to a particular utility and a particular class of service. The remaining expenses are common and must be apportioned between the utilities on a fair and reasonable basis."

(*b*) " The laws of Wisconsin place a municipality, which owns and operates a public utility, under the same obligations as any other owner of a public utility. The Commission considers that the general functions of city government and the supplying of private needs should be kept separate and each be self-supporting. "

From Wisconsin Railroad Commission, in 1915 (leading state utility commission in the country):

(*a*) "A municipal water plant or electric plant should be treated as an enterprise, separate and distinct from the municipality itself, and the accounts kept accordingly."

(*b*) "A city operating its own water plant or electric plant should pay the utility at a reasonable rate for service rendered the city, and the utility should pay the city a reasonable amount as taxes and as interest on the city equity in the property of the utility, in order to avoid unjust discrimination in favor of either the taxpayers or the consumers."

Extract from article of George H. Hooper, Operating Superintendent, Water Works, at Winnipeg, Manitoba, in "Fire and Water Engineering" magazine of September 6, 1922:

"The water works system or utility of any city, town or municipality, while under the control of the council or governing body should be absolutely separate and self-supporting. All surplus money earned in any one year should be set aside to take care of renewal of mains and that portion of the service under the control of the system.

"I believe the system in vogue in certain places to hand over the surplus to general revenue is wrong in principle, and takes away from the water works branch the right to make necessary changes, construct new works or renew parts of the system needing same, without going to the council for the money, with the result that the request is sometimes only partly complied with or refused on account of lack of funds.

"A water works department should receive payment for every gallon or cubic foot of water delivered, whether it be to a civic department or to the private individual."

The Comptroller of the City of Savannah, in 1917, stated:

"The water works department, while it should not be operated at a profit, should be able to provide a depreciation fund, should take care of all extensions and betterments, should pay the interest on its bonds and provide a sinking fund for the redemption thereof, and furthermore should yield to the city some return on its investment. This last point is recognized by Richmond, Va., and Holyoke, Mass., both of which cities tax the water works department."

Memphis, Tenn. (1917):

"The water works plant is operated as a distinct department of the city, administered by three commissioners with separate officers and separate treasury."

From "Engineering and Contracting" magazine of May 8, 1918 (extracts from annual report of Chief Engineer of Alhambra, Cal., Water Works, for 1917):

"The business of supplying water is of a different character than that of any other municipal industry at the present time. . . . All other departments are primarily disbursing agencies, expending allotted funds on pre-determined work. The water department is, however, a commercial enterprise, possessing requirements similar to other public *utilities*. . . . To be operated well and continuously its financial success must be certain in order to meet current obligations, to maintain the desired standards and to adequately provide for the growing demands. . . . thoughtful planning is necessary in order to forecast the future service requirements and to insure successful operation and substantial building."

Jacksonville, Fla. (1917):

"The accounts of the water works have always been kept separate from other municipal accounts; the cash receipts from the water works are entirely separate from other receipts and the moneys are kept in a separate account. Funds for the purpose of necessary renewals and replacements are set aside from time to time. The water department also contributes its proportion to the general sinking fund of the city." (This must of course be for taking care of water bonds only?)

The following abstracts taken from a copy of "Reprinted Editorials in the May 5, 1915, Issue of the Engineering and Contracting Magazine" furnish a notable illustration of how some of the western states and cities are leading the way to better things in water works administration, and special attention is called to the same, even by those of us who may have read the articles when published and possibly have forgotten them now.

Referendum passed by Fargo, North Dakota, in 1915:

"Water works men, the country over, will be interested to learn that the first use of the referendum in the State of North Dakota was at Fargo, on April 6, at which time a new water works ordinance was passed by popular vote after the Board of City Commissioners had refused to pass it. The ordinance . . . provides for the abolition of 'free water,' creates a water works fund and subsidiary funds, including a depreciation fund, and makes illegal the use of this water fund for other than water department expenditures." (Fargo had then a city commission of five members, covering water, streets, finance, police, and fire matters, and all the members were "men of energy, ability, and unquestioned integrity.")

"Failure of the members to agree on the water ordinance was not due to personal antagonism. The difficulty arose out of the division of the city government into revenue and non-revenue producing departments, and *out of the natural tendency of men not to show but to shift the true expense of their department upon another department having an independent source of revenue.*" The Water Commissioner "was unable to bring his fellow commissioners to his viewpoint with reference to water finances, and so appealed directly to the people, with the result already stated."

"Under the conditions which have existed in Fargo the City Commission has in a sense been a water board of five members, four with official interest in water finances adverse to that of the water commissioner." (Then follows the description of how each wants water for his especial department, but without showing its expense in such department!)

"Under the new order of things, since the passage of the water ordinance, the other departments will have to pay for water used and for the readiness of the water department to serve them. *The true expenses will be more clearly defined in all departments.* It will no longer be possible to re-appropriate money from the water works fund for general municipal expenses."

Then follows this further *editorial* comment and significant statement:

"*'Free water' has played such a prominent part in loose and misleading forms of municipal accounting, thereby retarding the efficiency and economy movement, that we are always glad to see a city abolish it.* The Fargo experience is of interest, as it shows that where the subject is properly agitated, as it was in that city, the people can be made to see the point."

The Fargo ordinance provides in Section 1 that the

"*Municipality shall Provide by Taxation for Water Used, Wasted, or Donated by It.*"

In the issue of the "Engineering News" of September 4, 1913, appeared a very interesting description of the drastic provisions of a water works ordinance passed by the City of San Diego, Calif., on April 28, 1913, which also illustrates the western progress in some of the matters now under discussion.

Besides many interesting and progressive provisions of this ordinance, an unusual but absolutely just provision is required (in addition to making the various departments of the city pay from their special funds into the water fund for all water used by them) and as follows:

"With the consent and approval of the Common Council special rates of less than 8 cents per 100 cubic feet (the regular rate prescribed) may be granted to public works, charitable institutions, and others in special instances; *but in every instance where a special rate is thus granted, the balance between it and the regular rate must be paid the water department out of the general fund!*"

In other words the water works in San Diego must no longer be made the "Municipal Goat."

It is always a matter of wonderment to me why city councils and other local governing bodies and officials do not appear to take seriously the recommendations and opinions of their water works officials, who must in a way become specialists in their line and keep well informed as to the progressive practices in their business, and whose conclusions when sought by outside officials or governing bodies in distant cities are generally given more weight and consideration. I suppose the only explanation lies in the traditional expression about the "prophet without honor in his own country," or similar expression.

Some years ago I had one personal experience showing clearly the ever present political influences which for a time may be slumbering beneath the surface of things, and which I cannot forget.

A certain Mayor of Springfield (who must be nameless) owed his election largely to one of the leading local politicians, and in making inquiries of me as to the management and status of municipal water works, and in particular concerning the Springfield Water Works, stated that his special reason for asking the information was due to the fact that this politician had been urging him at the very commencement of his term of office to use his influence in trying to bring the water works under full control of the local City Council, and had exerted some pressure (such as politicians know how to use) in that direction.

This Mayor, being satisfied that the water works independent administration would continue to be for the best advantage of the community, demanded the politician's real reason (other than certain fallacious argu-

ments submitted), and after repeated demands for such reason, the politician finally hung his head and said "*Well, we want to get our hands in it*," or words to that effect!

This Mayor, in spite of pressure, had the courage of his business sense and told the politician he could not conscientiously be a party to any such effort.

It seems to me that this experience, of itself alone, is sufficient incentive for the setting up of *an ideal* and to keep it ever in mind, notwithstanding we may never hope to fully realize its possibilities.

I strongly believe that if we could get all parties to seriously consider the same view-point sufficiently together, some progress towards the ideal might be made. But the difficulty seems to be that each side is not thinking of the same thing at the same time, and thus continue to remain apart. This phase of the matter brings to mind an old anecdote which illustrates the difficulty, although in a humorous sort of way.

A village youth and his sweetheart were quietly strolling one blissful Saturday evening in summer along the shaded village street past the little country church where the amateur village choir was discordantly rehearsing for the following Sabbath performance; while in the tree-tops outside the usual insect-orchestra of the season was holding forth as only such natural performers can; said the gallant swain (listening to the struggles of the choir), "What a dreadful noise they do be making, Jennie!"; replied the dreaming maiden (listening to the katydids), "Yes, John, and they say that they do it with their legs!" Could you imagine two souls to be further apart at the moment?

Well, it seems to me that it is just about so in attempting to put the matter of water-works administration properly before local authorities; some appear to have the village choir in mind, while others cannot forget the katydids; and so there you are!

Why should a municipal water works not only be kept and operated entirely independent of the so-called governmental "Departments" of a town or city, but controlled and regulated by some authoritative body of specialists, like the state public utility commissions, rather than by the local political bodies?

The honest and unprejudiced seeker for light upon this question has only to read of and observe the evils and failures of the many attempts at *political control* throughout the country during the years past, with its utter lack of following the common *business* practices and needful uniformity of the privately-owned successful public utilities, and his best self-interest will answer the question for him. I venture to state that the average business man, if the matter could be placed before him in a clear and logical manner, would agree that the local political control of any utility, which is supposed to efficiently serve him and the public (of which

he is only a part), is not as safe and impartial as that of a higher outside body of so-called specialists.

In connection with this matter of *control* I wish to offer a few authoritative opinions and abstracts, which in themselves will, I am sure, prove to be of valuable assistance at this time.

In "Engineering and Contracting," issue of May 5, 1915, we find the following prophecy:

> "The regulation of municipally-owned (water) plants is sure to come."

A former president of this Association (and superintendent of a large privately-owned water works in New England) in a paper presented in 1914 made the following statements:

> "A further remedy which has been suggested to assist water-works managers to put their plants on a business-like and practical basis would be the placing of *municipal water works* under the same supervision by state public-service commissions as other public-service corporations, for, after all is said, the municipal corporation has the same need of supervision as the private corporation."

Abstract from January, 1917, "Monthly Rate Letter" of Norton, Bird and Whitman (engineers, Chicago and Baltimore) in commenting on the "Progress of State Regulation" of Public Utilities:

> "Experience in those states where the *municipal utilities* are subject to the same regulation as private companies has shown that there is a greater need of regulation of municipal than of private utilities. Only in those states placing municipal and private utilities on the same basis can fair comparisons be made between municipal and private ownership and operation of utilities."

"The American City" magazine of September, 1920, gives a description of several western cities where state control has been very successful, and the immediate administration of water works has been placed under Boards of Trustees and of Commissioners, and entirely separated from local political bodies.

The Omaha, Nebraska, water plant is conducted (*subject only to the control of the State Legislature*) by the Metropolitan Water District of Omaha, under a bi-partisan board of six directors, elected by the district for six-year terms.

The General Manager states, in his letter of September 26, 1917:

> "It is the aim of the Board of Directors of the Metropolitan Water District to conduct the water plant as though it were a private enterprise."

Among the state commissions now exercising an accounting control, etc., of municipal water works are those of Maine, Connecticut (last year), Pennsylvania, New Jersey, Wisconsin, Indiana, California, Washington, Montana, and Nebraska.

Abstract from Address of Martin J. Insull (retiring President of National Electric Light Association) at 1921 Convention in Chicago. ("Public Service" magazine, July, 1921):

"The day of municipal control of utilities has gone and we are in the period of state control, with the possibility that in the time of many of us here we shall have reached the stage where, due to further developments, interstate control may become advisable. With the passing of the period of municipal regulation there has necessarily largely passed the day of municipal ownership."

The water works at Portland, Maine, are controlled by the Trustees of the Portland Water District, which district has "exclusive control and management of the water works." The legislative act, creating such district, declares said district to be a "Quasi-municipal corporation" with power through its Trustees to borrow money, issue negotiable interest-bearing notes of the district, pay all legal obligations of said district, etc. At the 1916 annual convention of this Association in Portland its Mayor stated that the Portland Water Works is out of politics and is managed by a non-partisan commission of men who know *sound business principles*, and who employ only experts to administer its affairs. (This is like having a state public service commission right on the ground at all times, it appears to me).

Another former president of this Association (one of the leading water works and utility engineers in this section of the country) in an address to the Association in 1916 expresses the opinion that

". . . the control of public utilities by public service commissions, or like regulating boards, is probably the best solution of the present day issues between the public and the corporation. . . . The public, and the corporation as well, can derive benefit only from the regulation of utilities by an able and impartial commission. This is equally a fact whether the utilities be owned by corporations or by the public themselves; and the writer would not be surprised to see the jurisdiction of the commissions more generally extended in the near future to cover matters relating to the accounting, financing, and making of rates of *municipally-owned* utilities."

In the Editorial Section of "Public Utilities Reports" for April 27, 1922, appear these remarks:

"One of the most important advantages of state regulation of utilities over local control is the opportunity of having uniform accounting methods such as have been prescribed by the state commissions. This would not be possible under city supervision. The value of this, both to the utilities and the public, should not be lost sight of. . . . Another advantage of commission supervision of utility accounting, once its purpose and scope are understood, will be its tendency to engender better relations between the utilities and the public."

The entire editorial article, from which these abstracts are taken, is well worth careful reading by those having access to this publication.

I cannot refrain from calling special attention to the following abstracts from an editorial article in the "Engineering News-Record" of November 16, 1922, entitled "Regulation of City-Owned Utilities." This is the very latest expression from one of the most looked-up-to authorities in this country, and is worthy of absorption at the present time. I quote most of the article, as follows:

"The wide extent to which privately-owned municipal water works have been put under state control while those owned by the cities have generally been left scot free, except as regards the sanitation of water, has led a subscriber to suggest a 'campaign looking to the financial control by state utility commissions over municipally-owned and operated water works' in order to promote 'business' rather than 'political' administration. . . . Wisconsin is a notable instance of state control of some phases of the financial administration of city-owned water works. Apparently the plan has been beneficial in that state. The extension of the plan might well be given attention, now that most of the legislatures will soon have their biennial session. Strong objection may be expected from the 'home rulers,' of whom there are many. The extremists in this class object even to state control of privately-owned utilities, claiming that the cities themselves, untrammelled, should do all the regulation. The argument in favor of a reasonable degree of state control of municipally-owned water works is stronger than that against."

It would seem that enough authoritative argument has here been offered (by quoted opinion and comment) to show conclusively the real need of and trend toward some legislative action to insure the proper independent *business administration* of municipally-owned water utilities, and also a reasonable control over same by the state commissions. But opinion and comment are one thing, and effective action is quite another thing; as shown by the following amusing incident, for which I can personally vouch.

Some years ago one of the leading churches in Springfield used to hold a popular service of praise and conference on Sunday evenings, under the energetic leadership of its pastor, who was in the habit of wandering around the room and making the service a lively one. At one of these services, after several hymns had been sung and interesting experiences given, a stranger arose and proceeded to tell how glad he was to be present, and how he now felt impelled to a higher plane of living. In solemn, measured tones he said, "My friends, from this hour I *aim* to be a better Christian; I *aim* to be a better man; I *aim* to be a better husband; I *aim* to be a better father; I *aim* to be a better neighbor; I *aim* to be" —— Just then the nervous pastor, anxious to give out another hymn, from the rear of the room exclaimed, "*Pull the trigger, brother, pull the trigger!*"

I leave with you the application, by analogy, of this incident to the matters herein presented for your further consideration.

In concluding this altogether-too-long paper, I wish to state that my *Ideal* is to see every water works utility which is owned and operated by a

town or city in the State of Massachusetts entirely removed from local political influence and control, and placed under the control and regulation of some proper form of a bi-partisan state public-utility commission composed of men chosen because of their special fitness and training.

I would also include in the foregoing regulation the desirability of establishing by legislative action the permanent independence and separation of such water-works utilities from the local political governing bodies, and the placing of same in charge of local non-partisan Boards of Trustees or Water Commissioners of three or more members (preferably five), who shall be chosen by the people, or by some higher and competent authority other than the local political governing bodies or officials; such members to receive a nominal remuneration or none, and to serve for terms of five or six years each, not more than one member to be elected or re-elected in any one year.

I am aware that I may be called " a visionary " by the " home rulers " and the politicians, but many years of experience and observation have strongly confirmed me in my conclusions.

The probability that few of us will realize our *Ideals* in our lifetime should not permit the lowering or the abandonment of them; but rather let us hold to the hope expressed in the following verse of an old school song, as I remember it:

" There's a good time a-coming, boys,
A good time coming;
We may not live to see the day,
But earth will glisten in the ray
Of the good time a-coming! "

TOPICAL DISCUSSION.

Electrically Operated Gates.

[*September 13, 1922.*]

Mr. Percy R. Sanders.* Is any one present who operates a high service and a low service system, which has an electrically operated gate between the two systems that is opened in case of fire; and if so, how is it maintained and operated?

Mr. Fred O. Stevens.† I think we have at Weymouth the arrangement that Mr. Sanders alludes to, but in our case, the division between the two systems, comes in front of the station, and the valve is operated from the pump room only. We do that regularly and turn the high pressure into our gravity system at each alarm of fire in the gravity district.

Mr. Sanders. Who do you have operate it?

Mr. Stevens. The engineer.

Mr. Sanders. He is not on duty all the time?

Mr. Stevens. It happens that he is practically all the time. He lives just across the yard, and is required to stay within call.

Mr. Sanders. Have you any trouble with the service?

Mr. Stevens. None at all. Of course if there is a weak spot on the gravity system it will show up under the added pressure. The system was designed for the high pressure, and has been operated that way for thirty-five years. It is a little different from the case of a system designed for low pressure and then suddenly turn the high pressure into it.

Mr. Sanders. You shut it off when the fire is over?

Mr. Stevens. Yes, immediately. As a matter of fact, we operate it every day. There is a high section of the town which has not many houses, not large enough to spend much money on for high service, and we get by, by having individual tanks in the houses, and giving them a half hour of high pressure every day to fill their tanks, so that the valves are operated every day in that way.

Mr. Herbert C. Crowell.‡ In Haverhill we have high and low pressure service, and in several sections of the city have both the high and low pressure service in the same streets. The low pressure reaches about 40 lb. and is furnished in all those sections of the city. We also have the high pressure pipes there for fire purposes, and the high pressure takes care of the high elevations. In case of fire we do not have any trouble with them

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† Engineer and Superintendent, Water Works, Weymouth, Mass.

‡ Superintendent of Water Works, Haverhill, Mass.

because the high pressure pipes are all over the city. In the old days it was customary to turn the high service into the low service, and as many of the mains were old so much pressure burst them. Today we do not do that. When fire service is installed in a building, connections are made to both high and low service, requiring two checks and two valves. The high pressure is on the service regularly, but if the high is shut off at any time the low service operates on the service. We formerly supplied all the low sections with the high pressure service, and used a reducing valve, made by the Union Water Meter Co. The mains were practically all cement and in very bad condition. A bad conflagration occurred there three years ago, and I opened up the reducing valve on the second alarm and we sat on it for two or three hours, regulating the pressure by closing down the reducing valve. If we had not we would have blown the whole thing up to the sky. Since that time the mains have all been re-laid, and the system is now all high pressure service.

Mr. J. M. Diven.* The great trouble with electrically operated valves is that when the fire is over somebody might forget to close the valve and leave the high pressure on. I should like to change the question and ask about the automatic regulator valve from high to low.

Mr. Sanders. Then you have to be feeding the low from the high all the time, don't you?

Mr. Diven. Only when it goes down.

Mr. Crowell. This valve we had, from high to low, was a regulating valve. It would operate by a lever and weight, and could be set at any pressure desired. If you wanted 40 lb. pressure it could be set at that, and use the hose at 40 lb.

Mr. Diven. If you had 40 lb. on your low from some other source your regulating valve would be closed until your pressure on your low service went below some certain point, would it not?

Mr. Crowell. We had about 100 lb. pressure on the high pressure side of the valve and had it regulated to reduce to 40 lb.

Mr. Diven. All the low pressure is supplied through the high service valve?

Mr. Crowell. We were supplying it all at that time.

Mr. Diven. If the regulating valve on the low service went down to 15 or 20 lbs., something too low for use, would the valve operate?

Mr. Crowell. Yes, the valve would operate very nicely, and hold the pressure right at 40 lb. all the time.

* Secretary American Water Works Association.

Operation of Hydrants by Those Outside the Water Department.

Mr. George F. Merrill.* What is the custom in regard to the operation of the fire hydrants in some of our different towns and cities? Are all the Street and Sewer Department men allowed to operate them under all conditions, or is it customary for the Water Department to furnish a hydrant man?

Mr. Stevens. From the Water Department standpoint I should very much like to furnish a hydrant man in every case, and I have no doubt every water works man has the same feeling, but it is not always practical. In Weymouth it has seemed best to get along in the old way, by letting them operate the hydrants and making the best of it. That is not an ideal condition, and I do not like it, but it seems the fairest to all concerned.

Mr. J. M. Diven.† I think many of the water works have regulations prohibiting the handling of the hydrants by other departments, but since the Stillson wrench has come into existence it is pretty hard to control those matters.

Mr. Stevens. The Moth Department in our town is the greatest user of town water, and as their funds are limited, it seems almost too much of a hardship to make them pay for an extra man to operate the hydrants. It would mean several extra men, as they have several gangs. The best we can do is to charge up any serious damage they do, and to take care of it by inspection. I can't see any other way out of it for fair sized towns. We must use unbiased judgment in these matters, and not allow our zeal for perfection in the Water Department to cause too much hardship to the town as a whole.

Mr. Diven. Would it be reasonable to require any other department using the fire hydrants to notify the Water Department that such a hydrant had been used, so that they could see that it was in proper condition?

Mr. Stevens. In the case of the Moth Department, we trace them right through the town, follow them from day to day.

Mr. David A. Heffernan.‡ We do not let anybody use the hydrants outside of the Fire Department and the men on the steam roller, and those men have been taught how to operate the hydrants.

In regard to the Moth Department, the Moth Department superintendent takes a man from each gang with one of my men and he is shown how to operate the hydrants. We in return place in his hands a 2-in. meter that is to register the amount of water used from each hydrant, and we look to the Moth Department for perfect control. After the men have been instructed we find as a general thing that it works out all right.

I think it is a poor policy to let every department use your hydrants.

My attention was drawn the other day to a hydrant that was used the night before by the Fire Department, and I examined the hydrant myself.

* Superintendent of Water Works, Greenfield, Mass.
† Secretary American Water Works Association
‡ Superintendent, Water Works, Milton, Mass.

There was a low spot nearby which contained quite a pool of water, and I got four turns of the hydrant. So that even the Fire Department men, who are using the hydrants constantly, fail.

Mr. Charles W. Sherman.* Mr. Heffernan's remarks bring to my attention the conditions found in Belmont. We have had quite a number of complaints from the Fire Department of hydrants not being in proper condition. We made arrangements that our hydrants in town should be examined jointly by the Fire Department and the Water Department, each department to report at the end of the inspection. It turned out that about three out of five wrenches in the Fire Department were not proper wrenches and did not fit the hydrants. We got that cured, and since then they have worked together better. We have succeeded in getting the heads of the other departments to recognize the desirability of letting the Water Department control those things. The Board of Aldermen, in charge of the Street Department, has issued orders to the Superintendent of Streets that the Street Department men should not touch the hydrants, and we agree on our part that, if it is at all possible to do so, we will send a man to operate the hydrant and not charge for him. We have found that to be worthwhile. It does not cost very much money and it has materially reduced interference with the hydrants.

Mr. Merrill. I might tell you a little experience of a neighboring town. They allowed somebody around a certain mill to use a hydrant to flush a room, and forgot to shut the hydrant off. In this particular case it used up about a million gallons a day, and took considerable time to find out where the water had gone. It shows what may happen in a small system to make it inconvenient.

In Greenfield we try to furnish a hydrant man for the operation of all hydrants, and I believe it is a big saving on repairs, and also gives you a pretty good check on where the water is going.

Mr. Stevens. This has raised a question that has troubled me a great deal — not so much regarding the actual damage to hydrants, but as to how far we shall strain to get ideal conditions. To furnish this hydrant man would mean five or six men in my town on duty all summer. That would be fine for the hydrants, but I did not feel justified in loading on this expense when as a matter of fact the actual damage done to hydrants is relatively very small. It seemed better to use a little judgment than to lay down rules for an ideal condition.

* Of Metcalf & Eddy, Boston, Mass.

REPORT OF COMMITTEE ON MASSACHUSETTS LAWS RELATING TO FINANCING OF MUNICIPAL WATER WORKS.

In the absence of the chairman, Mr. Bertram Brewer, Mr. Leonard Metcalf presented the report of the Committee, as follows:

The Committee appointed to confer with Massachusetts officials concerning laws relative to the financing of municipal water works reports its conclusions and recommendations as follows:

This is not the first time this subject has come before this Association. In 1916, Messrs. Sherman, Johnson and Symonds presented a paper on legislation governing water works financing. At that time, largely through the efforts of these members of the Association, the limitation of law which required that serial bonds should be retired for payment beginning one year from the date of the loan, was changed to three years. But the efforts made to secure more equitable provisions concerning the period for which money could be borrowed for extensions did not meet with success. A comprehensive statement of the study and effort made at that time is to be found in the JOURNAL, Vol. XXX, page 279.

As the laws now stand, with respect to borrowing for water works purposes, they are —

"Section 8. Cities and towns may incur debt, outside the limit of indebtedness prescribed in section 10, for the following purposes and payable within the periods hereinafter specified:

. . . .

"(3) For establishing or purchasing a system for supplying the inhabitants of a city or town with water, for the purchase of land for the protection of a water system, or for acquiring water rights, thirty years.

"(4) For the extension of water mains and for water departmental equipment, five years."

. . . .

(Chapter 44, the General Laws.)

It was suggested last fall to the president of this Association that the present was an opportune time to review the matter. A conference was suggested with the special commission of 1922, appointed to investigate problems of municipal expenditures, with a view to securing particularly a general law which would provide for longer term loans than five years for water works extensions. Several meetings were held by the Committee to discuss a program and the December meeting of the Association was devoted to the subject of water works financing and accounting at its suggestion.

At the request of the Committee, Mr. C. W. Sherman was added to its membership on account of his long study of the problems and connection with the 1916 activities. It may be said that as a result of its deliberations, the Committee reached the unanimous opinion that five years is too short a period for borrowing for extensions and renewals in most cases where large mains, enlargement of supply, filters and other major undertakings are involved. At the same time the Committee was not insensible to the dangers of making the water department a source of revenue to the city for other than water works purposes, on the one hand, and, on the other, from the selfish desire of the vote getter to reduce the rates even to the point where the returns would not take care of legitimate expenses. The five-year term for bonds does not seem to have checked these tendencies, but rather to have led to a frequent resort to special legislation.

Since the Commission on Municipal Expenditures was directed by the Legislature to " investigate and consider," and specific acts would naturally follow, not precede, such activities, your Committee agreed to submit to it certain principles which in its opinion should govern laws affecting water works financing. These principles were explained, advocated and urged upon the Commission at a hearing held at the State House on December 27, 1922, with the suggestion that changes in the present laws should be made to conform to them. An offer of service was made in connection with the drawing of specific acts.

It was made clear that there had not been time to present the matter to the New England Water Works Association for its formal approval.

The basic principles submitted to the Commission were as follows:

1. There should be some provision of law requiring the application of revenue received from water service to the payment of water works expenses, including:

(*a*) Expenses of operation and maintenance,

(*b*) Payment of interest charges, sinking fund and serial payments on bonds issued on account of the water works,

(*c*) A sufficient sum for replacements, which shall be expended for replacements and extensions, to cover the costs which may be considered as annually recurring, that is, those which have to be met each year under ordinary normal circumstances, but excluding periodic major betterments. Said sum shall be not less than 10 per cent. of the gross revenue.

Water department revenue should either be made available for these purposes without appropriation by the City Government or Town Meeting, or the appropriating body should be required by law to appropriate sufficient funds for the purposes cited from the water revenue.

2. It should be made the duty of all water boards, commissioners or other boards or officers in whom the power of fixing water rates is vested, to establish water rates adequate to produce sufficient revenue for the purposes mentioned under (1) above.

3. For the purchase or construction of water works systems, or for additions, extensions and improvements (other than such annually recurring extensions as should be provided for from water revenue) cities and towns should be empowered to borrow money outside the debt limit, —

(*a*) On 30-year serial bonds (unless particular conditions should make some other term more appropriate,

(*b*) To an amount such that the total outstanding debt on account of the water works, without deduction for any sinking fund, shall not exceed the total cost of the said water works system.

4. The board, commission or officer charged with the care and operation of a municipal water works system, should annually make a report to the city, town, water or fire district, including a statement of physical operation, of revenue and expense, of extent of the works, of their total cost to date and the outstanding indebtedness incurred on their account, and a forecast of the income and expenditures of the ensuing year.

5. If it is deemed necessary to make the propriety and sufficiency of water rates, the amount and term of bonds, and the method of accounting and report, subject to review or regulation beyond the general limitations outlined above, then some commission or board having continuous existence, experienced in such matters, and having a competent engineering staff, should be given jurisdiction over such matters.

No word has been received as to any contemplated action by the Commission in this matter. Its report to the Legislature is due on Wednesday, the 10th instant.

In submitting this report, your Committee suggest that the matter need not be dropped here. A petition with an accompanying bill can be presented to the Legislature before next Saturday embodying either all of the changes urged, or only the most important change, — in the five-year limit now placed on borrowing for major works. With the approval and endorsement of this Association, it is not at all impossible that a change can be effected.

The Committee is ready to undertake this or other action desired by this Association. Otherwise it asks to be discharged.

BERTRAM BREWER, *Chairman.*
LEONARD METCALF,
A. R. HATHAWAY,
CHARLES W. SHERMAN.

REPORT OF COMMITTEE ON STANDARD SPECIFICATIONS FOR CAST IRON PIPE AND SPECIAL CASTINGS.

The last report of your Committee was made in September, 1920, and a further utterance, telling something of our stewardship in the interim, is now in order.

Two years ago the question of the adoption of a uniform outside diameter occupied the centre of the stage; you will recall that a questionnaire, sent to our membership, resulted in a strong endorsement of the uniform outside diameter, 85 per cent. of the replies received being in favor of this change. Practically the same expression of opinion, somewhat less emphatic, resulted from a questionnaire sent to the members of the American Water Works Association; in this case 70 per cent. of the replies were in favor of the uniform outside diameter. Unfortunately, 10 per cent. only of our active members, and 4 per cent. only of the American Water Works Association responded to the questionnaires. Under these conditions the results could not be given much weight.

The Joint Committee of the two associations then sent out in May, 1921, 138 letters to a selected list of consulting engineers and men directly in charge of water systems in cities with a population in excess of 100 000, asking the following questions:

1. Do you believe that a provision for a uniform outside diameter for all classes of pipe of the same nominal diameter, up to some limiting size, should be included in the revised specifications?
2. Would you, if pipes cast with a uniform outside diameter were available, immediately recommend their use in your own work?

The replies were as follows: —

Question 1 — Yes 40 — No 45 — Indefinite 14.
Question 2 — Yes 40 — No 38 — Indefinite 21.

This result is distinctly at variance with those obtained in the two previous questionnaires and must be given consideration as all the men addressed were closely in touch with water works distributions systems either in an advisory or executive capacity. Your committee has, therefore, placed the question of uniform outside diameter in the background for the present and have not recently discussed it with the manufacturers who are opposed to such a requirement.

The centrifugal process, mentioned in our last report as an interesting development in the making of pipe has passed the purely experimental

stage and is now employed in one foundry in the United States in commercial production. The few tests available indicate a considerably greater strength, but about the same total deflection for the iron in this pipe in comparison with that produced by the usual sand cast method. If a strength should finally be proved sufficient to justify a lesser thickness, there would be argument both in the decreased thickness and in the method of manufacture for the use of a uniform outside diameter for this type of pipe.

One notable advance has been made in an agreement with the manufacturers that a definite relation between flexure and breaking load is logical and advisable; in attempting to determine such a relation for incorporation into our revised specifications it was found that the necessary data did not exist, largely owing to the varying conditions under which test bars have been cast and broken in the past.

The manufacturers then arranged that Dr. Richard Moldenke, a metallurgist of established reputation, should make a series of tests of a large number of bars cast in the same manner, at different foundries throughout the country, determining the breaking load, deflection and tensile strength of each bar, and at the same time, the chemical composition in any attempt to find a relationship between chemical qualities and physical tests.

Dr. Moldenke's report, submitted September 21, 1921, is a very able, valuable and voluminous one. His investigation involved the making and testing of 800 bars cast in eight different foundries, four drawing on northern material and four using southern material. His finding in regard to the advisability of a chemical requirement is adverse on the grounds that either a physical or a chemical requirement alone should be specified, that the analysis of a test bar may be quite different from that of the pipe metal, that the inter-relation of the different constituents precludes the possibility of such a requirement being satisfactory, etc. He does, however, agree that the total sulphur content should not exceed .12, an amount .02 in excess of that named by your committee in its tentative revision proposed in 1917.

The tentative specification for test bars submitted to the manufacturers called for a transverse breaking load of not less than 1 900 lb. with a deflection of 0.30 in. at this loading and an increasing deflection of .025 in. for each increment of 200 lb. above 1 900. The iron used in Dr. Moldenke's test did not meet the above specifications and his tentative conclusions were that they are too severe for present foundry practice.

At a meeting with the Foundrymen's Test Bar Committee in April, 1922, your committee were not prepared to accept the apparent "letting down of the bars" which Dr. Moldenke's report indicated, in view of the fact that the existing specifications are being successfully met in practice; thereupon the manufacturers again generously undertook to finance

further investigations by Dr. Moldenke, it being agreed that Mr. Conard of the Joint Committee should collaborate in the work. This second report has just been received and has not yet been considered at a meeting with the manufacturers. It is again voluminous and is a noteworthy addition to the available information concerning the difficult subject of relation between flexure and breaking load. In it, 650 test bars broken in a representative northern and a representative southern foundry are considered. It is hoped that this question may be definitely settled at an early meeting with the Manufacturers Test Bar Committee.

No definite progress has been made towards specifying an improved coating, and without funds for scientific investigation, the road to achievement is difficult. There is being used, at the present time, on a certain contract, a refined coal gas tar coating which gives promise of being a marked improvement over the coatings in common use. It is possible that in this result may be found a basis for revised specifications.

Your committee was appointed in 1912; a similar committee of the American Water Works Association having been appointed in the previous year. In 1916, a joint committee, consisting of three representatives from each association, was formed and in 1917 a tentative draft of revised specifications was submitted to the manufacturers. It is therefore apparent that we have been making haste but slowly. The principal reasons for lack of results have been, at the outset, the opposition of the manufacturers reflected in unnecessary delay, and the fact that the world war precluded progress, the thoughts and energies of all concerned being centered elsewhere. For the past two years, the manufacturers have coöperated in a satisfactory manner, spending freely of their funds to aid our investigation, yet our objective has not yet been attained. Your committee realizes that its progress reports cannot, like the historical brook, go on forever, but that the end must come at an early date in the form of revised specifications.

One of the outcomes of the meetings with representatives of the Foundrymen's Association was the suggestion that a joint research committee be appointed to make a broad investigation of pipe foundry methods and materials and suggest improvement. Your committee endorses the formation of such a committee, whose results should aid the foundries in fulfilling the specifications to be adopted. We are convinced, however, that tentative specifications, embodying knowledge now available should soon be issued for the use of the Association, even though agreement may not be reached with the foundrymen on all the points now at issue.

A communication has been received from the Assistant Secretary of the American Society of Mechanical Engineers making a tentative suggestion that the American Engineering Standards Committee be asked to call a conference looking to a larger committee to consider all kinds of cast iron pipe and fittings with a view to simplifying and reducing the number

of standards. Your committee is of the opinion that the Association should join in this work, if it is decided upon, but that our revised specifications should be in no wise delayed thereby, as they would serve as a basis relating to a phase of the more comprehensive work of the proposed new committee, which in any case could not report for several years to come.

F. A. McInnes, *Chairman*,
F. A. Barbour,
W. R. Conard,
Geo. A. Carpenter,
Geo. A. King,
Committee.

PROCEEDINGS.

Annual Meeting.

Boston City Club,
Boston, Mass., January 9, 1923.

The President, Mr. Frank A. Barbour, in the chair.

The following were duly elected members of the Association:

Active: Thomas W. Proctor, civil engineer, Chestnut Hill, Mass.; Arthur L. Gammage, chemist, Winthrop, Mass.; Walter F. Garland, superintendent, Dracut Water Supply District, Dracut, Mass.; E. C. Hopkins, vice-president and treasurer, Crystal Water Co., Danielson, Conn. — 4.

Associate: Reinstatement to membership of Ware Coupling & Nipple Company, Ware, Mass. — 1.

The following reports of the Association were received:

Report of the Secretary.

January 2, 1923.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past year, and the general condition of the Association.

The present membership is 825, constituted as follows: 9 Honorary, 738 Active, and 78 Associate Members, there being a net loss for the year of 3. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1922.	Honorary Members	10			
	Died	1			9
January 1, 1922.	Total Members			742	
	Withdrawals:				
	Resigned		21		
	Dropped		22		
	Died		7	50	
				692	
	Initiations:				
	January		2		
	February		3		
	March		4		
	June		15		
	September		16		
	November		2	42	

	Reinstated:			
	Member resigned in 1915	1		
	Member resigned in 1920	1		
	Member dropped in 1921	1		
	Elected 1921, qualified 1922	1	4	738
January 1, 1922.	Total Associates		76	
	Withdrawals:			
	Resigned	3		
	Dropped	2	5	
			71	
	Initiations:			
	January	1		
	March	1		
	September	3		
	November	2	7	78
January 1, 1923.	Total membership			825
January 1, 1922.	Total membership			828
	Net loss			3

Members Elected in 1922.

January. Allan F. McAlary and Arthur D. Weston. (2)

February. Egbert D. Case, Karl R. Kennison and F. W. Scheidenhelm. (3)

March. Harold W. Baker, Harrie M. Howe, George E. Newbury and Joseph J. Turner. (4)

June. M. S. Bronsdon, Herbert E. Cushman, Charles J. Crump, Albert C. Dickerman, John D. Dwyer, Frank P. Hall, Franklin Henshaw, Stephen Kearney, Frank T. Lamey, James A. McKenna, William W. Peabody, Frank E. Waterman, George L. Watson, Charles M. Whitaker and Burton L. Winslow. (15)

September. John Brown, Julius W. Bugbee, Steve C. Burghardt, Henry S. Charron, Edmund Dunne, A. A. Gathemann, John E. Gleason, W. S. Lea, Ernest E. Lothrop, Alexander McDonald, Joseph W. Money, Chester A. Moore, John W. Mulcahy, Gilbert H. Pratt, Humphrey Sullivan and Ellsworth B. Tolman. (16)

November. Richard S. Holmgren and John L. Morton. (2)

Reinstated:	
Resigned in 1915, M. J. Look	1
Resigned in 1920, Henry Newhall	1
Dropped in 1921, Mayo Tolman	1
Elected in 1921, qualified in 1922, Alfred Betant	1
	4

Associates.

January. Metalium Sales Co. (1)

March. Mathieson Alkali Works, Inc. (1)

September. George A. Caldwell Co., New England Refining Co., and Red Hed Mfg. Co. (3)

November. Chase Metal Works and Fields Point Mfg. Co. (2)

Honorary Member.

Died: Robert C. P. Coggeshall. (1)

Members.

Died: E. J. Chadbourne, T. C. Gleason, F. M. Griswold, H. L. Hapgood, A. E. Martin, C. E. Peirce, F. L. Pierce. (7)

Resigned: George Cassell, J. Frank Ellis, S. F. Ferguson, J. W. du B. Gould, W. B. Goentner, F. J. Gubelman. W. E. Johnson, Beardsley Lawrence, Estus H. Magoon, H. Dallas McCabe, B. D. McConnell, E. T. McDowell, Henry Richards, H. L. Schuldner, R. W. Sherman, D. C. Shull, H. T. Sparks and W. C. Tannatt, Jr., L. M. Wachter, W. E. Whittaker and Nisbet Wingfield. (21)

Dropped: S. A. Agnew, James Aston, F. S. Broadhurst, C. C. Carlisle, C. F. Catlett, D. A. Decrow, C. P. Hsueh, T. N. Kapoustine, M. B. Litch, D. F. McCarthy, G. A. Miller, Dr. W. J. O'Sullivan, J. H. Remick, J. W. Routh, G. A. Sanborn, G. H. Sargent, A. N. Talbot, Chen Tan, Mayo Tolman, E. A. Weimer and J. P. Young, J. G. Whitman. (22)

Associates.

Resigned: The Fairbanks Co., Greenfield Tap & Die Co., and Linus G. Read. (3)
Dropped: Continental Pipe Mfg. Co., Flower Valve Mfg. Co. (2)

Receipts for 1922.

Initiation fees			$268.00
Annual dues:			
Members	$4 479.08		
Associates	1 520.00		
		$5 999.08	
Fractional dues:			
Members	$53.50		
Associates	25.01		
		78.51	
Past dues		6.00	
Total dues			6 083.59
Advertising			2 810.00
Subscriptions			395.00
Journals sold			150.59
Sundries			319.27
Total			$10 026.45

There is due the Association:	
Advertisements	$180.00
Journals	15.00
Reprints	21.00
Specifications	8.25
Total	$224.25

FRANK J. GIFFORD, *Secretary.*

Report of Treasurer.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$238.67
Initiation fees	$268.00	
Dues	6 083.59	
Total received from members		$6 351.59
Received from Estate of Hiram F. Mills		500.00
Journal:		
Advertisements	$2 810.00	
Subscriptions	395.00	
Journals sold	150.59	
Sale of reprints	142.25	
Total		$3 497.84
Miscellaneous:		
Sale of "Pipe Specifications"	$7.25	
Membership lists	5.00	
Buttons	2.00	
Certificates of membership	34.50	
Exchange	.50	
Interest (Old Colony Trust Co.)	8.77	
Index	1.00	
June excursion	118.00	$177.02
Total receipts		$10 765.12

Expenditures.

Journal:		
Advertising agent's commission	$304.20	
Plates	3.25	
Printing	4 276.96	
Editor's salary	375.57	
Editor's expense	23.22	
Reporting	338.24	
Advance reports	16.20	
Reprints	490.70	
Stationery and postage	178.54	
Total		$6 006.88

Office:

Secretary's salary	$200.00	
Assistant Secretary's salary (to June 1)	480.00	
The Affiliated Technical Societies of Boston	1 490.43	
Assistant Secretary's expense	45.32	
Rent to June 1	312.50	
Printing, stationery and postage	51.24	
Telephone	19.39	
Total		$2 598.88

Meetings and Committees:

Stereopticon	$30.00	
Dinners for guests	37.50	
Music	46.75	
Printing, stationery, and postage	453.78	
Badges	66.78	
Miscellaneous	30.06	
Total		$664.87

Treasurer's salary and postage	$51.00	
Certificates of membership	68.00	
Miscellaneous	23.85	
Total		$142.85
Total expense		$9 413.48

FREDERIC I. WINSLOW, *Treasurer*.

In account with the NEW ENGLAND WATER WORKS ASSOCIATION.

RECEIPTS.		EXPENDITURES.		
1922.		Bills paid		$9 413.48
Jan. 1. Received from Treasurer	$2 414.97			
Received from Secretary	10 026.45	ON HAND.		
Interest on bonds and deposits	238.67	Framingham National Bank	$29.80	
Estate Hiram F. Mills	500.00	Liberty Trust Co.	1 264.21	
		People's Savings, Worcester	1 466.53	
		Mechanics Savings, Reading, Mass.	243.77	
		Check in hand	762.30	3 766.61
	$13 180.09			$13 180.09

ASSETS AND LIABILITIES.

ASSETS.			LIABILITIES.	
Cash in banks and Check in hand		$3 766.61	Surplus	$5 513.94
Bonds Nos. 2642 and 2644 Lake Shore and Michigan Southern R. R. 4s, due May 1, 1931		1 815.00	Bills payable	291.92
Accounts receivable:				
Advertising	$180.00			
JOURNAL	15.00			
Reprints	21.00			
Specifications	8.25	224.25		
		$5 805.86		$5 805.86

FREDERIC I. WINSLOW, *Treasurer*.

Report of Auditing Committee,

We have examined the accounts of the Secretary and the Treasurer of the New England Water Works Association and find the books correctly kept and the various expenditures of the past year proven by duly approved vouchers. The Treasurer has also accounted to us for the investments and cash on hand as submitted in the above reports.

E. D. ELDREDGE,
S. H. TAYLOR,
Finance Committee.

Report of the Editor.

To the New England Water Works Association: I present the following report for the Journal of the Association for the year 1922.

As has been the custom the figures are for Volume XXXVI and not exactly the calendar year of 1922 and represent total charges and accounts paid or payable rather than actual cash received or disbursed.

The accompanying tabulated statements show in detail the amount of material in the Journal.

Size of Volume. The Volume contains 801 pages, an increase of 241 pages over that of 1921.

Reprints. Twenty-five reprints of each paper have been furnished to the author without charge, where desired.

Circulation. The present circulation of the Journal is

Members, all grades	825
Subscribers	91
Exchanges	14
Total	930

One more than a year ago.

Journals have been sent to all advertisers.

Advertisments. There has been an average of 35 pages of paid advertisements with an income of $3,232.00. An increase of $310.92 over Vol. XXXV.

Early in 1922 a special drive was made to increase the volume of advertising in the Journal. A partial list of firms of high standing, dealing in water-works supplies was sent to each member with a letter requesting the member to make an effort to interest the firms in advertising in the Journal and in Associate Membership.

In response fourteen firm names were added to the list of advertisers and the annual income from advertising increased as above reported.

Further coöperation of the members along this line should be of much advantage to the Association.

Pipe Specifications. During the year the specifications for cast-iron pipe to the value of $6.00 have been sold. The net gain up to a year ago had been $337.35 so that total net from this source to date is $343.35 and 20 copies of specifications on hand — $5.00 worth if sold at retail. Two copies were furnished without charge to the committee on Standard Specifications for Cast Iron Pipe.

Post Office Account. The association has a credit of $2.35 at the Boston Post Office, being the balance of money deposited for payment of postage.

TABLE 1.

Statement of Material in Volume XXXVI Journal of the New England Water Works Association, 1922.

Pages of

Date.	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates	Total	Total Cuts
March	140	16	156	0	39	4	0	199	11
June	155	12	167	0	40	4	2	213	36
September	149	10	159	0	40	4	1	204	23
December	131	5	136	4	40	4	1	185	21
Total	575	43	618	4	159	16	4	801	91

TABLE 2.

Receipts and Expenditures on Account of Volume XXXVI Journal of the New England Water Works Association, 1922.

Receipts		*Expenditures.*	
Advertisements	$3 232.00	Advertising agent's salary and commission	$ 317.20
Sale of Journals	150.59	Printing and plates	4 510.16
Sale of reprints	142.25	Mailing postage	159.45
Subscriptions	395.00	Editor's salary	300.00
		Editor's incidentals	15.82
		Reporting	338.24
		Reprinting	713.23
	$3 919.84		
Net cost of Journal	2 434.26		
	$6 354.10		$6 354.10

Respectfully submitted,

HENRY A. SYMONDS, *Editor.*

TABLE 3.

Comparison between Volumes XXVI to XXXVI Inclusive (omitting Volume XXXI), New England Water Works Association.

	Vol. XXVI. 1912.	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1915.	Vol. XXXII. 1916.	Vol. XXXIII. 1919.	Vol. XXXIV 1920.	Vol. XXXV. 1921.	Vol. XXXVI. 1922.
Average edition (copies printed)	1 000	1 000	1 050	1 325	1 500	1 388	1 200	1 150	1 100	1 100
Average membership	740	745	803	904	1 002	954	902	885	864	826
Circulation at end of year	826	858	951	1 079	1 155	1 010	1 002	970	929	929
Pages of text	401	554	564	596	538	398	566	359	399	618
Pages of text per 1 000 members	542	746	702	659	538	417	627	406	462	748
Total pages, all kinds	567	733	719	776	707	557	726	520	560	801
Total pages per 1 000 members	766	984	895	859	707	584	805	588	648	970
Gross Cost:										
Total	$2 476.55	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$1 967.99	$5 011.03	$5 381.84	$6 354.10
Per page	4.37	4.89	4.65	5.47	4.79	5.59	6.84	9.64	9.61	7.93
Per member	3.35	4.81	4.17	4.68	3.38	3.26	5.51	5.66	6.23	7.69
Per member per 1 000 pages	5.90	6.46	5.80	6.02	4.79	5.85	7.59	10.88	11.12	9.60
Per member per 1 000 pages text	8.35	8.68	7.39	7.85	6.30	8.19	9.74	15.77	15.61	12.47
Net Cost:										
Total	$98.81	$1 322.90	$1 155.33	$2 091.09	$1 171.98	$691.50	$2 675.04	$1 722.14	$1 869.85	$2 434.26
Per page	.17	1.80	1.61	2.70	1.65	1.25	3.68	3.31	3.34	3.01
Per member	.13	1.78	1.44	2.32	1.17	.73	2.97	1.95	2.16	2.95
Per member per 1 000 pages	.23	2.42	2.00	2.98	1.65	1.31	4.09	3.75	3.87	3.68
Per member per 1 000 pages text	.33	2.42	2.38	3.88	2.17	1.83	5.25	5.43	5.43	4.77

Report of Committee on Revision of Standard Specifications for Cast-Iron Pipe.

Mr. Frank A. McInnes, chairman, presented the report of the Committee.

Report of Committee on Massachusetts Laws Relating to Financing Municipal Water Works.

Mr. Leonard Metcalf presented the report for the Committee.

The President. Mr. Metcalf, do you care for any action of the Association approving your course to date?

Mr. Metcalf. Mr. President, the Committee felt that perhaps it was wiser to see whether this meeting wished to initiate any action.

It seems to me that there should be such action; that the Association should present through some suitable man a bill covering, certainly, the change in the five-year limit. Whether you want to go farther than that or not without a thorough discussion of the subject, I will leave the meeting to determine. You know the viewpoint of the Committee.

The President. If you want action I believe a motion suggesting that the Association approve the course of the Committee to date and continue the Committee, and give them power to enter a bill along the lines you suggest, would serve the purpose.

Mr. Metcalf. If that power was given it would be acted upon by the Committee.

Upon motion, duly seconded, it was voted that Association approves the course of the Committee on Massachusetts Laws Relating to Financing of Municipal Water Works, continues the Committee, and gives it power to enter a bill along the lines suggested.

Adoption of New Constitution.

The President. The principal business that we have before us this afternoon is the discussion of the general amendment of the Constitution. In the notice of the meeting it is stated: "Proposed General Amendment of the Constitution to the Revised Form shown on enclosed pamphlet." This printed form has been sent to all members. This announcement was in accordance with the present Constitution, which requires that an amendment shall be sent out in printed form to the membership.

Discussion and amendments followed.

On motion of Mr. Samuel E. Killam, duly seconded, it was voted that the Revised Constitution as a whole, as amended, be adopted.

THE PRESIDENT. I will now call upon the Tellers to report the result of their count of ballots.

The Tellers appointed to count the ballots reported as follows:

REPORT OF TELLERS JANUARY 9, 1923.

Whole number of ballots	272
Number not signed	3
Number counted	269

President.

PERCY R. SANDERS	261
Scattering	2
Blanks	6
	269

Vice-Presidents.

GEORGE A. CARPENTER	266
REEVES J. NEWSON	263
DAVID A. HEFFERNAN	264
FRANK E. WINSOR	264
THEODORE L. BRISTOL	264
VERNON F. WEST	266
Scattering	1

Secretary.

FRANK J. GIFFORD	264

Treasurer.

FREDERIC I. WINSLOW	264

Editor.

HENRY A. SYMONDS	265

Advertising Agent.

FRED O. STEVENS	268

Additional Members Executive Committee.

FRANK A. MARSTON	264
STEPHEN H. TAYLOR	265
GEORGE A. SAMPSON	266

Finance Committee.

A. R. HATHAWAY	266
E. D. ELDRIDGE	265
ARTHUR N. BURNIE	265

PRESIDENT BARBOUR. You have heard the result of the election, and I want to take this occasion of thanking you for the support you have given the Executive Committee and myself during the past year. Fortunately for me, and for you, the present Constitution does not require of the President a retiring address.

It gives me great pleasure to introduce to you the in-coming President, Mr. Sanders.

Mr. Percy R. Sanders. Gentlemen of the New England Water Works Association: I wish to thank you very much for this honor that you have conferred upon me, and to express my appreciation of the good will which you have shown.

We are rather proud, up in Concord, of our connection with this Association. While not a charter member of it, our membership goes back to 1886, and has continued without a break down to the present time.

I would also like to express my appreciation of the New England Water Works Journal. The papers as printed in this Journal form a record of achievement in water works construction and maintenance and sanitation that cannot be excelled, and I doubt if it can be equalled.

I would earnestly ask your coöperation during this coming year that we may keep the type of papers that are presented to the Association of the same high grade that we have always had.

I thank you, gentlemen. (Applause.)

Papers.

A paper on "Cement for Water Pipe Joints," was read by William Wheeler, Consulting Engineer, Boston.

A paper on "Some Costs of Lead Substitutes in Pipe Joints," was read by Vernon F. West, Treasurer, Rensselaer (N. Y.), Water Co., Portland, Maine.

A paper on "Some Data on Pipe Jointing Compounds" was read George Finneran, Superintendent Water Service, Boston, Mass.

The President. I find that there are some twenty-two committees outstanding in this Association, very few of which are acting. The Executive Committee today recommends the discharge of thirteen of these twenty-two committees. On account of the lateness of the hour I think we had better let that matter go over until the first meeting of the incoming administration.

But I do think, in view of the adoption of the Constitution, the Committee on Revision of the Constitution had better be given a clean discharge at the present time.

On motion of Mr. Frank A. Marston, duly seconded, it was voted to extend the thanks of the Association to the Committee on Revision of Constitution, and that the Committee be discharged.

(*Adjourned.*)

FRANK ELWOOD HAMMOND.

Frank Hammond, as he was familiarly and affably called by his friends, the son of Hartson and Sarah (Clark) Hammond, was born on Deer Hill, in China, Maine, on July 11th, 1856. He died on the 17th of March, 1922.

Until nearly fourteen years of age his life was incident to that of the hardy son of the soil which taught him the important lessons of independence, perseverance, economy and thrift, all of which stood him in good stead throughout his life.

His first acquaintance with letters was made in the little country school house where so many of the sturdy boys and girls of Maine have first engaged in the measuring-up process between the experiences of the farm life and the magical glamour of the great outside world which is so appealing to youth, which seems so real, so easy of attainment and which, alas! is so frequently far from even worth the while! Just before reaching his fifteenth year he moved, with his father, to Fairfield. He attended the Fairfield High School and entered Coburn Classical Institute where he remained for several terms. At twenty he was employed by the Duren Brothers, Manufacturers of Lumber, at Fairfield, as an accountant and served with them, in various capacities, for fourteen years. At thirty-four he went into the grocery business with his father, purchasing his interest after five years, taking over the entire business which he successfully conducted for twenty-six years, retiring in 1917.

Retirement did not, however, in any sense, mean idle leisure for him, for his time, since that event, has been fully occupied in constructive work, municipal banking and other activities which made for the betterment of the community.

He served as one of the Selectmen of the town of Fairfield for several years. For many years he was a trustee of the Waterville Savings Bank, its Vice-President and a member of the Executive Committee. He was a trustee of the Kennebec Water District, having been appointed in 1920. During the short time of this latter service he brought to the management of the Districts' affairs good business judgment, honesty of purpose, a broad view of its duties and requirements as well as a keen sense of its opportunities and responsibilities as a public-service activity.

On February 10th, 1881, he married Miss Jennie McIntire of Fairfield, who alone survives him. He was a Mason, being a member of various branches of that great institution.

In failing health for several months because of diabetes, yet his going came as a great surprise and a distinct shock to the entire community. A good business man, a kindly friend, a loyal husband, a genial gentleman, he will be greatly missed by all with whom he came in contact.

FREDERICK C. THAYER,
WILLIAM W. NYE,
Committee.

New England Water Works Association

ORGANIZED 1882.

Vol. XXXVII. June, 1923. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

REFORESTATION OF WATER-SHEDS.

BY PHILIP W. AYRES.*

[*Read February 13, 1923.*]

Mr. President and Gentlemen of the New England Water Works Association, — I want to acknowledge my thanks to a considerable number of persons connected with your Association, and to read extracts from what they have said:

The Portland, Me., Water District has been planting 20 000 trees a year for a number of years, at a cost of $20.79 per thousand trees planted. This is a little higher than average cost, perhaps, due to difficulty in preparing the land for planting. The information comes from Mr. James W. Graham.

Word comes from Mr. J. H. Reed of Manchester, N. H., that the Water Works are planting from 50 000 to 75 000 trees every year, and that their oldest plantations, which are about fifteen years old, are looking very splendid, and promise a good revenue in years to come. He sent a picture that will show in the lantern a little later. $1 265 00 worth of timber were sold from the forest of the Manchester Water Works in 1921.

Mr. James L. Rice of Claremont, N. H., reports that they have set 40 000 trees and that they are placing them six feet apart as a rule, but when they find a lot of undergrowth they just fill in the pines and use the undergrowth as nurse trees, which is a good thing under certain conditions.

Very interesting material comes from Newton, Mass., also from the Massachusetts Metropolitan Water Board, and from the New Haven Water Company, which the pictures will show.

From Franklin, N. H., Mr. J. P. Proctor, Treasurer, writes that they have already planted 50 acres and the experiment seems to be very good. He thinks it will be profitable in the long run, besides affording early protection to the water-shed.

From Springfield, Vt., the Manager, Mr. R. W. Wilcomb, writes that they have an excellent showing of trees ten years old. He wishes those interested would come up and look at them.

* Forester of the Society for Protection of New Hampshire Forests.

Much valuable material has been received from the Pennichuck Water Company of Nashua, N. H., through Mr. Arthur B. Graves, who has sent some pictures from which slides have been made.

Mr. Charles E. Warren, Trustee of Waterville, Me., Water District, writes that from six to fifteen thousand trees have been planted annually since 1905, about six feet apart. The result is encouraging, but they are

A Pine Plantation Twenty Years Old, Keene, New Hampshire.
The first thinning has a value sufficient to pay cost of removal.
Planted six feet apart.

finding difficulty from the White Pine Weavel that attacks the top shoot.

Mr. Sidney Lee Ruggles, Superintendent of the Barre, Vt., Water Department reports very interesting plantations of Norway spruce at a cost of $16.04 per thousand.

Let me ask your especial attention to the photographs from the Water Commissioners of Middletown, Conn., who have been planting for twenty years, since 1903, and have about two hundred acres to their credit. Their hardwood plantations, particularly oak, are very successful. They sold $459 worth of wood in the year covered by their latest printed report and have about two hundred planted acres. This information comes from Mr. Eben Jackson, Middletown, and from Mr. W. O. Filley, Forester of the State Experiment Station.

Some very interesting experiments in the re-distribution of native pine seedlings have been carried out on the water-shed of Hanover, N. H. These have been made under the direction of Professor Robert Fletcher,

a member of the Board and long Director of the Thayer School of Engineering at Dartmouth College.

From Concord, N. H., Mr. Percy R. Sanders reports having purchased in April 1908, twenty-five pounds of pine seed, which was set out in beds and later planted over the water-shed. The lantern pictures will show you the splendid results. Some of you are finding great difficulty in procuring small trees for planting. Let me commend to you the Concord way of starting a small nursery for your own use. It is practical and inexpensive.

I think that you will find interesting the following table of plantations in New England, by states. It shows much commendable work.

TABLE OF PLANTATIONS ON WATER-SHEDS IN NEW ENGLAND.

	Acres Owned.	Acres Planted.	Acres Available for Planting.
MAINE.			
Portland Water District	540	11	500
Kennebec Water District	305	42	75
Total reported	845	53	575
NEW HAMPSHIRE.			
Manchester Water Works	2 300	513	none
Pennichuck (Nashua Water Works)	900	700	150
Concord Water Works	400	150	75
Claremont Water Works	90	40	10
Jaffrey Water Works	150	135	15
Hanover Water Works	1 281	15	700
Hollis Town Forest	200	15	....
Warner Town Forest	800	5	....
Walpole Water Works	....	25	....
Franklin Light & Power Co	....	5	....
Total reported	6 121	1 603	950
VERMONT.			
City of Barre Water Dep't	334	10	40
Bellows Falls Dep't	400	25	50
Chester Water Works	....	7	....
Hardwick Water Works	1 000	100	500
Montpelier Water Works	....	88	....
Northfield Water Dep't	200	150	50
City of Rutland Dep't	289	220	none
Rutland Ry. Light & Power Co	3 000	30	1 070
South Royalton Citizen's Water Company	40	10	5
Springfield Village Water Works	50	12	25
St. Johnsbury Water Works	....	213	....
Woodstock Aqueduct Co	196	7	100
Lake Shaftsbury Association	....	2	....
Standing Pond Trout Club	....	4	....
Total reported	5 509	878	1 840

Massachusetts.	Acres Owned.	Acres Planted.	Acres Available for Planting.
Amherst	....	35	....
Athol Water Dep't	350	20	75
Attleboro	....	15	....
Brockton Water Dep't	100	40	38
Cambridge Water Dep't	778	75	500
Fall River (Watuppa Reservation)	4 000	100	100
Fitchburg (City Ownership)	1 550	200	500
Foxboro Water Supply District	33	8	5
Haverhill Water Works	863	10	75
Holyoke Water Dep't	3 200	200	1 000
Hudson Public Works	275	180	80
Leominster Water Works	90	60	30
Lowell Water Dep't	198	40	90
Marlboro Water Dep't	146	10	20
Needham Water Dep't	....	5	....
New Bedford Water Works	2 000	20	100
Newburyport Water Commission	70	20	....
Newton Water Dep't	600	180	300
Northampton Water Dep't	1 300	100	1 000
North Brookfield	....	5	....
Pittsfield Water Dep't	3 225	600	1 200
Southbridge Water Supply Co	1 482	15	900
Taunton Water Works	155	30	20
Uxbridge Water Dep't	44	10	6
Waltham Water Dep't	67	42	25
Westfield Water Dep't	3 240	100	500
Winchendon Water Dep't	300	250	none
Winchester Water Works	405	200	200
Worcester Water Dep't	3 000	500	100
Metropolitan District (Boston and vicinity)	10 330	2 200	900
Total reported	37 801	5 270	7 764

Connecticut.

(*a*) *Companies.*

New Haven Water Co	12 000	1 800	none
Bridgeport Hydraulic Co	13 000	450	600
Ansonia Water Co	2 200	200	25
Naugatuck Water Co	1 206	400	600
Norfolk Water Co	1 100	15	300
Greenwich Water Co	....	200	....
Collinsville Water Co	13	11	2
Woodbury Water Co	150	18	50
South Manchester Water Co	...	20	....
Torrington Water Co	4 401	75	1 500
Rockville Water Co	250	100	75
Thompsonville Water Co	64	5	30
Stamford Water Co	....	50	....
Birmingham Water Co	....	2	....
Jewett City Water Co	....	10	....
Southington Water Co	....	25	....

(b) *Municipalities.*	Acres Owned.	Acres Planted.	Acres Available for Planting.
Hartford Water Com'rs ...	7 200	500	200
Middletown Water Works...	1 036	175	none
New Britain Water Com'rs..	3 080	180	....
Wallingford Water Dept.....	844	50	150
Bristol Water Dep't......	1 200	40	600
Groton Water Dep't.....	.	30	....
Danbury Water Dep't...		10	....
Water Water Dep't........	..	50	....
Total reported..........	47 744	4 416	4 132

SUMMARY.

Maine........................	845	53	575
New Hampshire........................	6 121	1 603	950
Vermont........................	5 509	878	1 840
Massachusetts........................	37 801	5 270	7 764
Connecticut........................	47 744	4 416	4 132
Grand Total........................	98 020	12 220	15 261

PINE TREES FIVE YEARS AFTER PLANTING.
Concord, New Hampshire Water Works.

Rhode Island does not seem to have done much planting. The State Forester reports that there is a plantation at Woonsocket, and a very considerable plantation is proposed for the new water-works scheme for the city of Providence. I shall be glad to have further information.

Summarizing, the six New England States have planted approximately 12 200 acres, which have already considerable potential value.

Counting our chickens before they are hatched, when this timber comes to maturity it should be worth \$200 an acre easily, which will be \$2 440 000, enough to meet in part a possible war emergency. This is an admirable beginning, but what is 12 000 acres against the total amount of waste land we have in New England on our several water-sheds — much of which is not yet purchased.

The Timber Supply.

Let me speak a few minutes on the general bearing of these facts. I shall show you later a picture of the timber condition in this country

Trees on the Middletown, Connecticut, Reservoir Fifteen Years after Planting.

before any lumber was cut at all, and another showing what the Government has done in establishing national forest reserves, in different parts of the country. We ought to realize that in the United States we are approaching, slowly but very surely, a timber shortage. There is no doubt about this. The lumbermen and the leading foresters of the country at large agree that the timber which will give you houses, furniture and tools in the near future is not yet planted, and that our present supplies are approaching exhaustion.

William B. Greely, Chief Forester of the United States, has pointed out that four-fifths of all our remaining timber stands west of the Rocky Mountains, that four-fifths of all the people in the United States live east of the Rocky Mountains, and that there is a long haul between; and he points out that the long haul in coal does not always work out to our advantage and that long hauls in lumber are not likely to work out any better.

Now, we are, according to Mr. Greely, using up our timber in the country at large four and one-half times as fast as it grows. There must, therefore, be an end. You know we had the lumber market formerly in Portland and Boston. It then jumped to Buffalo, at the time when Pennsylvania hemlock came into general use. Then it jumped to Chicago, where it stayed from 1850 to 1880, while the Lake States supplied the growing country with thousands of houses to take care of the immigrants. When the Lake States were finished, it shifted to Memphis and then to Kansas City, where it stayed until nearly now. This was when the southern timbers came into use. They are nearly cut now. You who have finished off houses with southern pine at relatively cheap prices, will see comparatively little more of it. Southern pine at advanced prices is with us only for a little while. The Pacific Coast is now the timber market.

I saw on the streets of Boston yesterday a car load of paper pulp that was imported from Sweden, with notices upon each roll in German and in French, "Don't use any hooks upon this paper." We are already introducing foreign-made paper into this country, and that means that our factories are not manufacturing and that our own people are not employed. Now, you may put a high tariff on it, but if you do, where are you going to get your paper? The lumber that is coming from Oregon through the Panama Canal costs $15 to $18 per thousand board feet delivered in New York and Boston, and the building in which my office is located, within a block or two of here, has recently been made over, and some of the lumber that was used in it came from Oregon.

Now, New England is actually producing only 13 per cent. of the lumber that is used in it per year; and New Hampshire, which is my state, produces only 47 per cent. of the lumber that is used in New Hampshire per year. Vermont has the same percentage. We have in New England six million acres of idle, waste forest land that is producing not even inferior cord wood. We have in New Hampshire 1 900 000 acres of idle forest land that once produced magnificent forests, and ought to do so again.

Now, I mention all these things to you because they have a very direct bearing on the problem of you gentlemen who have planted the 12 000 acres, and who have made the first great, splendid beginning in New England that must be followed by many people in many ways. I think you have set an example. But I am also pointing out that 12 000 acres as against 6 000 000 acres of waste land is not sufficient to more than meet a single emergency.

Mr. Henry S. Graves, formerly Chief Forester of the United States, did a splendid piece of work in France in making ready for supplying the French and the English and the American armies with timber from the French woods, which the French people had been preserving carefully for nearly a century against the great emergency; and when he came back he said that if our war had come fifteen years later than it did, we in America

could not have built our own cantonments without importing lumber to make them, either from a great distance, the Pacific Coast, or from a foreign country — namely, Canada — at great inconvenience and delay.

Now, when you get responsible Foresters to say that, and when you get them backed by the President of the United States, Mr. Harding, who has said that it is a case of returning again to a position of self-defence in America, then you may be sure that the question is worthy of your attention, and that your plantations are likely to prove important to the nation as well as profitable to your selves.

You will be interested also in this, — the lumber that comes through the Panama Canal and pays from $15 to $18 freight rate, means that much of a differential in favor of your growing timber here at home at a profit. I do not believe timber will ever be grown in New England on a great scale except at a profit, and the conditions have not been right for a profit hitherto. The competition of original timber, which is still being mined in the far west, is such that it has not been profitable to grow timber in New England, and our tax system in most of our states has been such that it has been impossible for anybody to grow timber at a profit, except on publicly-owned land. We must change these conditions.

The Bearing of Forest Taxation.

I should like to add a word about forest taxation. For the water companies, it makes a great difference whether you are growing timber on private land or public land, because the private land pays taxes. In most of our New England States, except Massachusetts, no system has yet been worked out by which the tax on private forests will enable you to grow them at a profit.*

I think I can make this clear to you. Suppose you have a few acres of timber, and your annual tax amounts to $20, and you are to cut your timber thirty years hence. Whatever you pay in taxes if placed in the savings bank would draw interest for a term of years. All of these several sums paid in taxes at compound interest for thirty years, or twenty-nine years, or twenty-eight years, etc., must be deducted from the final sale value. Let me repeat. The first year you would compound your $20 for twenty-nine years; the next year the same for twenty-eight years; and so on till the last payment with interest for one year. Now, money in the savings bank will double in fourteen years so that your $20 becomes in fourteen years $40, and in twenty-eight years it becomes again $80. Therefore, you have $80, $79, and so on, which you have really paid in taxes, against the value of your few acres at the end of the thirty years. Now, unless you can regulate your system of taxes — I am speaking now to those who are planting on private land — you will find that they will

*Since the above was written, New Hampshire has enacted a forest taxation law by which growing timber on tracts of fifty acres or less, maybe exempted until the time of harvest.

Plantation of the Concord, New Hampshire, Electric Company in 1915.

Plantation of the Concord, New Hampshire, Electric Company in 1920.

The same location as the previous picture, five years later.

eat up all of your final profits completely, because from the period of planting until the harvest you have to compound those taxes and take them out of the final product.

The Idle Forest Land.

Now, we have in the eastern part of the United States 81 000 000 acres of idle forest land, and we are importing lumber from Canada, from Sweden and from the Pacific Coast to supply the greater part of the eastern part of the United States, excepting, of course, the South, which, as I said, will end up within ten years. It is estimated that 3 000 sawmills will go out of business in the South within five or six years. These are statements from official sources.

This is not a situation which Americans can first comprehend and then do nothing about. We have confidence, all of us, in one another and in the general American character and common sense, to know that to make these facts generally known is all that is necessary in our free land to get them corrected.

The Remedy.

And where does the remedy lie? Partly in Federal purchase, such as the White Mountains forest and in the southern Appalachians; partly in great state forests. New York has acquired 2 000 000 acres; Pennsylvania, 1 300 000 acres. Massachusetts has appropriated $3 000 000 by which the Conservation Commissioner shall acquire and plant up 100 000 acres of idle land in Massachusetts within fifteen years. That is merely a beginning. There are nearly 1 000 000 acres of idle forest land in Massachusetts, but you have made a fine beginning in getting the thing started by state action. But by far the most important part of the remedy lies in private planting, with such state and federal aid in taxation and otherwise as shall make private planting profitable.

Municipal Forests.

There is a great future for municipal forests in this country. Our problems approach the European problems more and more every year, owing to the increase in population and the scarcity of timber. With us in New England wood has doubled in price in the last ten years. All of you remember that ten years ago spruce and pine were exactly half what they are now.

There are in New Hampshire two municipal forests of especial interest because they are managed by Water Works Departments, and were acquired originally to protect the water-shed. One of these is the Keene forest of 1 800 acres of woodland from which $14 000 worth of lumber has been sold. My belief is that none of this was reinvested in the forest itself, that the limit in cutting which was six inches, amounts

The Middletown, Connecticut, Reservoir in 1915.
Plantation on the farther shore.

The Middletown, Connecticut, Reservoir in 1920.
The same location as the previous picture, five years later.

to very little and that future revenues to the city of Keene from this large timber tract are not as promising as they should be.

In contrast to this, 1 275 acres owned jointly by Dartmouth College and the town of Hanover are managed on a much wiser plan. The mature trees only are removed and the promise of future returns is excellent.

The movement for town forests in Massachusetts is very active, not only to protect water-sheds, but also to provide a future timber supply. Under the active leadership of the Massachusetts Forestry Association twenty-two towns and cities in Massachusetts have established town forests, while more than eighty others have official committees established to locate such areas and define the terms of acquirement. The town of Russell has acquired recently 1 700 acres for water-shed protection, and proposes to plant several hundred acres, the rest being timber land that is well stocked.

Summary.

Summing up, the situation is this: We have all of us to get into the game; everybody at his own house. We shall build well if everybody does that which is next him, and the municipal forest is the one which just now is nearest to us. Later we may plant profitably as individuals, but not now. I have been mighty glad to speak to you today because you are engaged practically in planting municipal forests; these lists I have read to you, are, practically all of them, municipal forests. Now this is a magnificent beginning, and I congratulate you. The only thing is, do not be discouraged in well doing, and continue, especially those of you who are planting on lands which are not taxed. In the long run much will be accomplished.

Now, I can say what I have said somewhat better by pictures, and as a number of those whose names I read, and some whose names I did not read, have provided lantern slides for you this afternoon, I am happy to be able to show them.

(Mr. Ayres then showed a large number of stereoptican views, during the showing of which the following general remarks were made):

Handling White Pine Seedlings.

White pine requires shade while the trees are small, and it will be to your advantage to get your own nurseries started so that you will not have to pay from $8 to $15 a thousand for your stock. The Portland Water Board wrote me that they were unable to get this year more than 1 000 little trees. That is, the State Nurseries and the private nurseries are sold out already, and if you have not gotten your orders in you will have to scurry around to get trees this year. The small nursery is practical if you are going to plant anywhere from ten acres up. By planting your seeds and covering them very lightly, perhaps putting a little straw over them, in the course of a few weeks they begin to germinate. When the

young white pine trees are in the beds, after the shade frames have been taken off, in their third year, they are taken and put in regular garden rows and taken care of just like garden plants. When you plant them in the field you need, as a rule, only small breaks into the soil. Two men can plant a thousand trees in a day,—if the land is reasonably open. Pails are used in the handling, because the roots of the little pine tree have to be kept moist from the time they leave the ground until they are in the ground again. If the roots of the pine tree get dry, the resin in them will

UNDER PLANTATION OF PINE, NEW HAVEN WATER COMPANY.

coagulate and choke the circulation so that the tree will always die. Therefore, be sure that the trees are kept in a moist condition; heel them in the ground and pour some water over them; keep the roots wet until put in the ground again.

DISTANCE APART.

If you plant your trees six feet apart, in time you will need to do some thinning, but at that distance you can make the thinnings when the trees are big enough to pay for their cutting.

DAMAGE FROM ANTS.

Now and then all of you will find some disturbances from big ant hills. We did not know what was the trouble until lately; we thought the ants carried some fungus in the ground which spread to the roots of the trees. But it has been discovered that this is not the case. The ants want the sunshine, and they deliberately girdle the pine trees around.

If you will look closely at the butts of the dead trees you will find that the ants in hundreds have nibbled clear around them, until they have positively killed the tree. How the ants know that girdling will kill I do not know, but they do it in order to let light in on their nests. I once visited the Middletown plantation down in Connecticut, and found considerable damage from the large ant hills.

The White Pine Blister Rust.

Let me tell you something about the White Pine Blister Rust. You are doomed if you do not keep the Pine Blister Rust out of your pine plantations; but I am glad to tell you it is a very simple thing to do. This is a disease which gets into the little needle at the end of the twig, and then runs down into the minor stem, and then runs down into the main stem and finally girdles the tree completely. It is very much like the chestnut blight, which has wiped off $300 000 000 worth of timber from New York, Pennsylvania and the New England States already. And the pine growth, which is worth more money by many million dollars than the chestnut ever was, is very near its end through this new disease, unless we keep the disease out. But fortunately we have now a method of keeping it out, namely, by carefully eradicating all currant and gooseberry bushes, both wild and domestic, from within at least one thousand feet of the pines. The disease develops on the currant and gooseberry bushes.

This is done at an expense of from twelve cents an acre on high land to $1.79 an acre on swamp land. I urge you to make sure you get it done. The cost is usually under thirty cents per acre. The State Forester will send crews of trained men to you, who are efficient, if you will merely pay the bill, and in New Hampshire literally hundreds of private owners have taken advantage of this offer. The same is true of Massachusetts, Connecticut and elsewhere. So be sure that you are free from this pest, and be thankful that you can be free from it.

The National Forest in the White Mountains.

You will be interested in the National Forest Reserves, that the Federal Government is establishing by purchase in the Eastern Appalachian Mountains. Congress has appropriated a total of $12 000 000, and something over $2 000 000 has been expended in the White Mountains. Forest land has been acquired (440 000 acres or 700 sq. mi.) at an average price of $6.23 an acre. It is estimated that that timber would now sell for a million dollars more than the total cost to the Government. It therefore has been an excellent investment. The White Mountain forest is now entirely self-supporting, and soon will return goodly revenues to the Government.

In this matter we owe a lot to a number of Massachusetts men. I was going to speak of John Weeks as a Massachusetts man, but I believe

we can fairly call him a New Hampshire man. John Weeks's grandfather was a member of Congress from the Northern District of New Hampshire. It is said that he had eight sons, all six feet tall, and that he used to line his boys up along the wall and say, "Look at them; look at them; I have fifty feet of boys." Well, we owe much to John W. Weeks.

We owe much to Dr. Edward Everett Hale, who surveyed the White Mountains when twenty years old, and sixty years later when Chaplain of the Senate worked to get the bill through that the White Mountains might be taken over by the Government.

Just one point about New Hampshire. There are comparatively few states that have made a survey of their forest lands and know what the condition is. We have made this survey. We have 29 per cent. of our lands in splendid, promising growths, but we are very sorry that we have a third of our state, very nearly 33 per cent., which is in idle, waste condition. The worst of it is that in New Hampshire, as in Massachusetts, and all the New England States, we are increasing the idle and waste area. We are cutting off in each of our states about 50 000 to 75 000 acres a year, about half of which comes back to good forest. To solve our forest problem we must plant as you are doing, but also we must change our methods of logging, and that right speedily, so that a desirable species returns upon the land, and so that our great unnatural areas of waste forest land are not made still greater.

Discussion.

President Sanders. There is one thing up in New Hampshire that we are mighty proud of, and that is our mountains and our lakes and forests; in fact, those are really the principal assets of the State.

About twenty years ago a number of the public-spirited men of New Hampshire got together, and they made up their minds that unless they did something pretty quick their lumber interests would clean those hills and mountains all off. In lumbering they did not take any particular care to dispose of the slash, to do any reforesting when they cut off, to look out for fires, or anything of that description. So these people got together and organized a little society — the Society for the Protection of New Hampshire Forests, — and everything that has been done in the forestry line in New Hampshire can be traced back to this Society. They have been back of every move, — reforesting, planting small trees, looking after fires and fire wardens, and planting shade trees; and the man who has stood behind all of those movements, the man who has put his shoulder to the wheel and pushed things through, is Mr. Ayres.

Now, Mr. Ayres I know will be very glad to answer any questions that anybody would like to ask him. Before that, I should like to ask if Mr. Orr is here; for if he is, I think we should like to hear a few words from him.

MR. ALEXANDER ORR.* *Mr. President and Gentlemen:* Under my direction one of the first municipal forests in the State of New York was started and is maintained. Our Board of Water Commissioners in the early nineties became convinced of the desirability of obtaining by purchase or otherwise the various acreages of land contained in our water-sheds. This policy was pursued for a few years until we finally found we had a large accumulation of land on our hands and it did seem a shame not to put it to some actual use.

Previous to 1908 we did a little planting by taking up seedlings around the old pine trees, with not very good success. In 1908, with the help of Mr. Whipple and the State Fish and Game Commissioner of New York State, we planted our first planting of seedling trees. There were 10 000 white and 10 000 Scotch pines. They were planted five by five. Each year subsequently we have planted from 30 000 to 120 000 trees.

In our accumulation of water-shed land, on one water-shed we acquired about two thousand acres. That was made up of an area of sixty acres of water, about seven hundred acres of grass land, gardens, pastures and fields of the farmers we had taken, and the balance of it was practically all hardwood. We then planted all those open areas with white and Scotch and red pine, and spruce. After a year or two we changed our method by making the spacing six by six.

The state of New York about that time commenced to encourage the reforesting of waste land in New York State, and urging it upon the people, who began replanting so much that the state supply of transplants became very scarce, and we inaugurated our own nursery. We continued that nursery over a period of ten years. Along about 1910 the scarcity of transplants was so great that we, with several others, imported from Germany through the State Department a number of pine trees. That importation finally, I think, probably did more to introduce the blister rust in the United Sates than anything that has ever been done. Those trees were in about six years, and we finally cut them all out and burned them.

As Mr. Ayres said, it is easy to eradicate the blister rust if you chase around and eradicate the wild gooseberry and wild currant bushes, but it is a pretty hard thing where you are surrounded by farmers who raise gooseberries and currants.

We also found another trouble with our white pine. We got our trees started along nicely, and along came the weevil and cut the leader off, and the result was that we have quit planting white pines altogether. We plant now only red and Scotch pines, and spruce trees. We plant on all of our open areas. We have trees that were planted in 1908 that are now twenty-eight feet in height.

One of our worst fears is the fear of fire. We had a fire two years ago in which we lost about thirty acres of Scotch pine. A match was dropped out of a wagon on a road passing through that section.

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* Superintendent Water Works, Gloversville, N. Y.

There was originally an electric railroad and three country highways running through the two thousand acre plot that I spoke of, and since we have acquired it we have built a private highway of our own through practically the center of it. We have succeeded in closing up the public highways entirely to the public. The electric railroad has been abandoned. Now, there is one thing for fire protection that we do. We keep the right of way of this railroad and a fifty-foot strip along the highways and our private highway mowed every year. We keep it stripped. There is no dry grass in it.

Another experience which we had with the fire which I spoke of was in a patch of Scotch pines which had been planted about nine years. Under those pines was from two to four inches of nice dry needles, good food for fire. When the fire got into those needles it did not take long to catch the lower dry dead limbs, with the result that we have growing there today probably not over one hundred trees, the rest being absolutely killed.

We are now starting in and going through the trees that are up in size, trimming the dead limbs off, and taking them out and burning them. I have been criticised by some foresters for taking out a few live limbs, but I think I would rather have a few knots there thirty-five years from now than not to have any trees.

Now, we found last fall in going through some of those plantations two or three places where evidently some camper had started a little fire on the pine needles and the fire had burned out, doing no damage to the trees.

For about two years we have been cutting off hardwood timber, and we use that as spare-time work for our workmen. This place is only three and one-half miles from the city. We can go there with a motor truck up to the time snow starts and on such days as the weather is not too severe. The cord wood is sold by the Water Department and bought pretty much by the employees. It has been a source of a great deal of satisfaction during the past few years in the coal crises.

The following spring we go over that same area and replant with evergreen trees. We figure in the course of years that particular tract of land will have the hardwood all cut off, and that following up the cutting with evergreen planting, by the time we get that done we are ready to start in cutting off marketable pine and spruce timber. We started in 1908.

I will say for New York State that there is a provision of the tax law by which reforested lands are exempt from taxation for a period of years. My recollection is that it is thirty years. The provision is that the lands which contain a certain number of acres shall not be located within a certain number of miles of a city of the first, second or third class. Unfortunately we can not get into that because we are too close. But that gave great encouragement to reforesting work in New York State. The intent of the law is that there shall not be any excess valuations put on the property until the end of the thirty years, and then assessed at a valua-

tion in accordance with the value of the standing timber on it. A few people have taken advantage of that provision, but the amount of red tape necessary, has nullified the benefits of the exemption.

The state of New York this year has made a tremendous effort to influence people owning waste land in New York State to take up this reforestation work. They are offering special inducements to land owned by divisions of the state like towns, counties and municipalities, like water-shed lands. This year I understand they will furnish them trees for nothing where a few years back they were furnishing for fifty cents a hundred — the highest price they charged to private owners was some four dollars and fifty cents a thousand for four and one-half year old white pines. I understand they have over 4 000 000 trees to hand out this year, and three months ago that allotment was entirely taken.

Mr. Richard A. Hale.* May I add one word? We are under great obligations to Mr. Ayres for coming here and talking to us today.

There are very few who realize how much work he has put in in connection with the White Mountain Reservation and the results which have been accomplished. I think those of us who have been in touch with him in connection with the water-power proposition of the Merrimack River realize what he has done in that respect.

In connection with that perhaps I might mention that there was a report by the United States Engineers published a few years ago in regard to reforestation along the Merrimack River, and the results in regard to stream flow. That was six or eight years ago. They made a study of a period of sixty-years' flow of the river at Lawrence with reference to the effect of cutting the forests over the drainage area. The results did not indicate any diminution or irregularity of flow which could be attributed to this cause and many other conditions had to be considered of greater bearing on the subject. A small undergrowth had sprung up where the forests had been cut which gave a partial protection to the ground and did not leave it entirelybarren. It is, however, very desirable to have a good forest growth over the water-shed to protect the moist humus of the soil.

* Engineer, Essex County, Lawrence, Mass.

THE DIESEL OIL ENGINE FOR WATER WORKS SERVICE.

BY DR. CHARLES E. LUCKE.*

[*March 13, 1923.*]

The subject before the meeting is not an ordinary one. We have come before you to announce what we believe represents a new era in water-works practice, one that offers possibilities fully as great as were brought in by the centrifugal pump and the steam turbine; this is the oil-engine-driven, water-works pump.

Water-works practice in the past has been characterized, in comparison with other branches of steam engineering, by two great distinctive features. One of these is very high thermal efficiency, higher than is obtained in any other branch of steam practice with equal size of units. The other feature of great significance is the recognition by water-works people of the value of investment, the importance at times of investing more money in first cost of installation to save fuel, and its justification by the high average load factor that characterizes a water-works load in comparison with the lower average load factor typical of central station loads.

Water-works engineering, or, rather, the steam engineering phase of water-works practice, has been in those two respects probably in advance of all other branches of engineering practice. In the course of time we have seen various new forms of steam equipment developed, reach a commercial stage, come into use and finally appraised in comparison with what went before. The steam turbine has come with its centrifugal pump and that added a totally new class of different types to what we had before, represented by a series of different kinds of piston-reciprocating steam engines and displacement pumps.

Looking back over this period of development of the steam turbine in the general-power field, one must note that parallel to it there has been another development, the consummation of which we are just announcing. This other development has been the internal-combustion engine, but particularly the Diesel oil engine, which is characterized by the highest thermal efficiency ever accomplished in any prime-mover burning fuel. That high efficiency was proved a quarter of a century ago. It has taken all this time to bring the engine to a point where we feel it is properly reliable, available in suitable forms and safe to use for water-works practice in competition with all kinds of steam installations, each case to be judged on its merits and the merits to be purely economic and in no sense prejudicial.

* Professor Mechanical Engineering, Columbia University. Consulting Engineer, Worthington Pump and Machinery Corporation.

In this situation Worthington is in a unique position, unique in this sense, that Worthington is prepared to build and has built, as you all know, every type of steam equipment and of every size, and is now embarking on the enterprise of offering for every type and size for which there is any justification whatever, a corresponding Diesel oil-engine, water-works equipment. One type of Diesel engine must be judged against another, one type of pump equipment must be judged against another, any steam equipment must be judged against any Diesel oil-engine equipment. Selection must be made on the same basis for all, the best for the local conditions, worked out on an engineering analysis of the facts, each engineer making his decision on facts, without opinion or prejudice making any difference whatever.

This, gentlemen, is the first announcement of such a position by any organization in the world, so far as we know, and it is particularly interesting to all concerned because Worthington makes the announcement with an unprecedented variety of experience and present variety of equipment as a basis for its judgment.

This judgment is supported by certain facts and principles, certain developments that have become stabilized, and it is worth while to review some of the high spots of the development to show what seems to be the fundamental basis for the confidence that we have and which we think will result in your confidence in the future.

The Diesel oil engine has been growing most rapidly on the commercial side in the motor-ship branch of its application and use. There are now on the seas some hundreds of motor ships, on long-voyage routes such as from Europe to China ports, and these have been operating long enough to have demonstrated the reliability and efficiency of the Diesel motor ship in competition with steam. This situation is particularly important when we come to consider water works because there is no load, no commercial or practical load condition for any prime mover, which so nearly approximates that of the water works, as the load of the engines of ships which go on long voyages where the engine may run without any change whatsoever in its revolutions or load for as much as two months, and then just stop long enough to unload, reload, turn around and repeat.

That progress, however real and substantial, is not in itself sufficient. The engines of these motor ships are large and they have to be brought down into smaller sizes to meet the load or the capacity requirements of the various kinds of water works. It is not good policy to start building water works with Diesel ship engines in just one or two sizes; it is better to wait until the entire field can be covered with what would be most suitable, as to size and type, one for one plant, and another equipment for another plant; to wait, in other words, until a fairly complete line of sizes and types has been made available. An additional development, therefore, was due to take place, the adaptation of the Diesel engine to smaller sizes, and that has now been consummated and become a reality.

Still further improvements are needed, however, for water-works use of Diesel oil engines, development of application or connection of the engine to the pump. Here it is necessary to recognize that the r.p.m. of good oil engines are normally much less or much greater than the r.p.m. of good pumps, centrifugal or displacement, so that gearing becomes necessary in most cases, although not in all. This gearing problem becomes most acute, or, rather, most difficult from the old-fashioned standpoint, in the gearing up of the centrifugal pump so as to get its best speed when the engine runs also at its own best but lower speed.

It is recognized that gear development has just completed a piece of history. Gearing has been a problem primarily, for the steam-turbine engineers and they have succeeded both in stationary practice and in ships in making good gear sets transmitting from a few horsepower to many thousands. Gearing has today reached a state that has never been before even approached in the history of machinery. What is being done now with gearing would have been pronounced, say fifteen years ago, as a hopeless impossibility. We now realize that we did not know at that time anything at all about gearing.

It may be said, therefore, that there are three great developments which together serve as the basis of what we now are approaching, the application of a Diesel oil engine to water-works practice. The three developments are, the motor ship Diesel engine, that is the first, next, the adaptation of the Diesel engine to smaller sizes, as small as one might please to have, and with a certain increase in simplicity at the same time, and thirdly, the development of gear practice.

Coming down to the engine itself, there are certain things that are fundamental, the understanding of which justifies confidence, and the realities and truths of which are responsible for what has already been accomplished. Without going into tiresome detail, it is, however, possible to show the essential simplicity and firm foundations on which the big ideas rest.

The first and the most important function to be performed in a Diesel engine is to get a charge of air into the cylinder. The next important function is to get a charge of oil into the cylinder. Then the important thing is to bring that air and that oil together in such a way as will insure ignition, and in such a way as will insure that the combustion which follows ignition shall take place at just the right rate, neither too fast nor too slow, because too fast makes abusive shocks and too slow loses efficiency. And finally, when combustion is completed, this contact between the fuel and oil must have been so accomplished as to leave no fuel unburned and as little as possible unused air or free oxygen in the exhaust.

Here, in a way, is the complete story of the functioning of a Diesel engine that is not common to other machines. It is these particular things that make a Diesel engine *Diesel* and distinguish it from everything else.

It is desirable to examine a few of these points in more detail. First, consider the air charging. There are two great systems of air charging and each is good, each is suitable, but each has a different most appropriate application or use, which is learned by experience.

According to the first mode of charging the cylinder with air, it is provided with two valves, always poppet valves, an inlet and an exhaust, and these two valves are actuated by cams which are timed properly on the cam shaft which is gear connected to the main crank shaft and runs at half speed. It may be said, therefore, that the first system of charging is a valve system form of charging, consisting of a gear-driven, half-speed cam shaft, with a set of cams for operating an inlet and an exhaust valve for each working cylinder, and this technically and commercially is called "the four-cycle system."

The second system of air charging has proved to be well adapted to smaller sizes where simplicity means most. This is the system of charging by simply cutting two ports in the wall of the cylinder, very much in the location characteristic of exhaust ports of the Unaflow steam engine. The two ports are opposite each other. One is simply a vent for exhaust gases to permit the pressure in the cylinder to drop to the atmosphere when the piston passes that port at the end of its stroke. Immediately afterward the air port on the opposite side is opened by the same movement of the piston to a supply of air made available at that port by a so-called "scavenging pump," at 2, 3 or 4 lb. pressure, depending on the speed. That air then blows in as a more or less gentle blast, blowing the exhaust ahead of it. Then the piston rises, closes first the air port and then the exhaust, and the compression follows. This is the "two-cycle system" of air charging.

The second system, two-cycle charging, while occasionally used for larger engines, is especially well adapted to small ones because it eliminates the gear-driven cam shaft and the two valves per cylinder, but it has to provide for its air supply by some kind of a scavenging pump or air blower. In the smaller engines the scavenging air displacement is accomplished by utilizing the under side of the working piston in any one of several more or less convenient fashions open to the taste of the designer.

So much for two systems of air charging. One engine will naturally compare with another as to details according to the taste of the designer or the judgment of the user, but between those two systems a first choice must be made.

Consider next the preparation of the air for fuel charging. After the air is in the cylinder, introduced by any one of these charging means, the second step to be carried out is one of preparation for the entrance of the fuel. That second step is a high compression, a compression of the air from whatever temperature it has at the moment the piston starts, to a value high enough to ignite any fuel that may be injected or projected into it. And that high compression is all there is to the ignition system of a

Diesel engine. The ignition temperatures of the various grades of fuel oil are subject to study by physicists who are interested in physical properties, and they give us values. It is a simple sort of calculation to determine how much compression of cool fresh air would bring about a final temperature of 1000°, 1100°, or 1200° Fahrenheit, which is about the range required for most fuel oils. The second stage of charging, then, is really not charging but a preparation for the entrance of the fuel and this is nothing more than the simple operation of compression, again very similar to what takes place in a Unaflow steam engine to superheat the steam in the clearance. Everything is now prepared for the entrance of the fuel and this is the second part of the main functioning system of the Diesel oil engine. The fuel is always delivered in the Diesel engine through a pump and the fuel pump is an accurate device that has metering properties or characteristics. The pump is a finely-made piece of mechanism that meters out most accurately a charge of oil suitable for the load and directly under governor or hand control. Every different designer has his own little details of fuel pump, but there is such a pump with that metering function on every Diesel oil engine.

The metered charge of fuel oil is delivered into the cylinder in either one of two characteristic ways, one quite different from the other. In the older standard air-injection system, compressed air is used to finally put the oil into the cylinder. The pump delivers the fuel, not directly into the cylinder but into the casing of a fuel valve located on the cylinder head, and that casing contains an air space and that air space is in communication with an air-pressure bottle, where the pressure is maintained by an injection air compressor at about 1000 lb., or sometimes less, and that air is constantly available and constantly maintained by the engine because the compressor is directly connected or attached to the engine itself.

There is in addition to this air space in the fuel-valve casing, a place to receive the pump delivery of fuel oil. There is in addition to these things in the spray-valve housing, a stem or valve proper which is cam operated by another cam, a fuel cam, and at the right time, which is about top dead center, the fuel cam operates the fuel valve and whatever oil is in the valve housing is blown into the cylinder. The air at 1000 lb. in the fuel-valve casing blows into the cylinder where the pressure is only half as much. The fuel delivered by the pump is deposited on extended metal surfaces, a sort of a labyrinthian surface arrangement in the valve housing, and it is just blown by the air flow over these surfaces. The fuel, therefore, is delivered into the cylinder by the flow velocity of this compressed air blowing past it into the cylinder. Now, the rate at which it enters is of course controlled by the surface of the metal to which the oil sticks and from which the air velocity tears it off.

All of this is the air-injection fuel-spraying system, which is the one used on all large Diesel engines. This system includes the following ele-

ments: A metering pump delivering a governor-controlled charge of fuel to a fuel valve on the cylinder head. Air under pressure and self-maintaining, acting also in the same spray-valve case. A needle valve through the casing, cam controlled. At the right moment the valve is opened and the air blows into the cylinder, carrying oil with it, at a rate depending on the air velocity and the resistance of the labyrinth that holds back the metered oil. By means of the rate control the combustion can be made fast or slow. The time when it starts to enter is a cam-controlled matter. The rate at which it enters depends entirely on the labyrinth, and that is always made adjustable, so for a thick oil it can be set one way and for a thin oil, another way, absolutely under the control of the operator. So the rate of combustion is controlled by flow conditions. The time of starting combustion is controlled by cams. Ignition, well, that just takes care of itself because the compression is so high that the fuel ignites as soon as it enters.

The second system of fuel injection is that known as solid injection, and it has been especially developed for use in the smaller sizes of engine, where simplicity is a matter of much greater importance, even at the sacrifice of some little refinements for efficiency. With the solid injection system the compressor for blowing the fuel into the cylinder is omitted. With no spraying air it becomes necessary to provide some alternative method of controlling the rate of entrance of the fuel into the cylinder, and therefore the rate of combustion, because that must not be too fast or too slow. This is accomplished by a special means peculiar to each different solid injection engine. However, common to practically all of them is this feature: that the pump now delivers fuel oil directly into the cylinder without interposition of any valve on the cylinder head at all, but there is of course a non-return check. Also common to all is the feature of having this pump not only act as a metering pump under governor but also a timing pump. It times the entrance of the fuel by its own connection to the cam shaft and therefore does within the pump what the fuel-valve cam did in the air-injection system.

There is left only one other function to be provided for and that is the control of rate of burning to avoid the shocks of too fast combustion and the losses in efficiency that go with too slow combustion. Every different solid injection engine has a little different scheme of controlling the rate of combustion peculiar to it and these cannot be examined in detail.

It is clear from these facts that the main idea, the basic scheme of operation in Diesel engines, is extremely simple. There is not the slightest element of mystery or uncertainty or unreliability about it. There are means for getting an air charge into the cylinder, for compressing it enough to ignite the fuel to come, for a proper injection of a metered quantity of fuel oil under governor control, with something to control the rate of combustion, and the time when the ignition or the injection shall start. Naturally the details of carrying out these principles will be different on each

different engine, quite the same as is the case with valve gears on steam engines, but each one of hundreds of varieties may be perfectly good if they conform to the standards built up by the experience of practice, and there need be no uncertainty today on these matters.

In addition to these main functions, which are so essentially simple in idea, conception or principles, there are certain other things which have to be carried out in order that the Diesel engine shall be an engine. The first of these, to distinguish them from those just discussed, may be called "preservative functions."

Any internal combustion engine must be provided with means for protecting itself against destruction. There are two classes of destruction to be considered, one common to all internal combustion engines but not found elsewhere, the other common to all machinery regardless of what kind. The first sort of tendency towards destruction, or the first influence which, if left uncontrolled, would cause destruction, is heat. Heat is generated in the cylinder of the Diesel oil engine at rates that range from low values to very high values and it is an interesting fact to note that the highest rate of combustion measured in b. t. u's per hr. per sq. ft. of combustion chamber exceeds the rate which is common to the most heated portion of steam boilers working under forced conditions. This means that the walls of the chamber in which the fuel is burned in a Diesel engine may be heated as intensively, and in some cases more intensively, than the fire-box plates of a locomotive or the tubes of a water-tube boiler in the range of the radiant heat of the glowing fire. Therefore, there is a tendency from this cause to destroy the metal, but that tendency can be controlled by the same sort of study of engines as has been carried out for the protection of steam-boiler tubes and locomotive fire-box plates and, again similar in another art also successfully executed, the water-jacketed bosh of the blast furnace.

The means whereby the metal walls of the combustion chamber of the Diesel engine are prevented from destruction by heat need not be examined in detail here. It is sufficient to say that we recognize the conditions and we recognize the relation of these conditions to the rest of engineering practice where heat in its effect on metal temperatures must be controlled, and that from all sorts of heat experiences in whatever art they may be found, conclusions are drawn for the solution of these problems.

As a basis of dissipating heat and as the fundamental basis of controlling metal temperature, the circulating water jacket is used. The jacket may be limited to the barrel of the cylinder or its liner, we may include the cylinder head, the piston may be included or not, water may be used or oil, and the water may be fresh, clean water or foul water. These are all questions of engineering that belong in the province of the designer and the installation engineer, and it is sufficient to say that they are now well understood and it is possible to meet any conditions that arise.

Along the line of preservation in the other direction common to all machinery, there are two divisions. The first is resistance to destruction by excess stresses. The preserving of machine members from excess stresses is no different problem in a Diesel oil engine than it is in any other kind of an engine or pump or compressor. This is simply a branch of ordinary machine designing. If the metal stresses due to the forces developed in a machine are computed, it is routine practice to apply the rules of machine designing that have been so many years in becoming established, to this case, and insure equal reliability against breakage.

On the matter of wear, which is the second item here, the situation is not entirely the same. Prevention of destruction by wear has, in some cases of recent development, followed new lines and succeeded, where the rules of old practice would have made these particular developments impossible. It is safe to say generally that wear is primarily the result of metal to metal rubbing contact and that prevention of metal to metal contact will prevent wear. It has been proved to be possible to come extremely close to preventing metal to metal contact by the very modern force-feed system of circulating lubricating oils. This circulating system of force feed of lubricating oil to the bearing comes near enough to prevention, by keeping the shaft or pin floating, to eliminate practically all wear in proportion as it is intelligently applied and more or less regardless, though not entirely so, of the quality of the oil. It is also pretty safe to say that without a force-feed-circulating system of lubrication there would be no modern steam turbines and no air-craft engines. The Diesel oil engine, especially in its motor-ship development, which has been the most remarkable, has adopted it and it is very doubtful if the success that has been attained would have been possible without it. Many early experiences, before it was adopted, were full of grief, but those have all disappeared and we are now on safe ground with the question of wear prevention, even with very high bearing pressures, judged by old standard practice with slow-moving machinery where the film had to distribute itself without the aid of a pump, constantly driving a great excess of oil between the rubbing surfaces with no regulation or adjustment whatever.

With this general idea as to the fundamentals of the Diesel oil engine, which can be expanded and illustrated at any length one may please, the present Diesel oil engine will be found in several different styles and types, each with great variety of detail but all having the same big ideas incorporated. There are available two-cycle engines, mostly in the smaller sizes, for simplicity. There are also available four-cycle engines, mostly in the larger sizes where refinements even with some complication are worth while and where the most intelligent attendance, by reason of size, is likely to be provided; so that there is first a choice between two-cycle and four-cycle, mainly on the basis of size, though not exclusively so.

Again, in the matter of style, practice recognizes a second basis of choice between horizontal as compared with vertical. There are vertical

stationary engines and horizontal stationary engines, thereby repeating the history of steam engine practice, and likewise high-speed and low-speed differences. There is not much to choose between them except in the ordinary sense of engineering as to what is best for local conditions. If equally well designed, it is fair to say that one is quite as good as the other, but not necessarily for the same service conditions.

Again, there are the air-injection engines as compared with the solid injection. The air injection is a little more complicated, but so far a little more perfect in handling the fuel oil. The solid-injection engines are quite satisfactory as far as reliability of service is concerned, but so far more or less confined to the smaller sizes, not so much because they can't be made in the larger sizes but because so far they have not been. Solid injection of fuel oil presents some little difficulty, requiring study to find good solution of the problem and all builders have not yet succeeded, but it is hoped that some day the same degree of simplicity now typical of the smaller solid-injection engines may become available in all the sizes. Just at present this is not true so that there are solid-injection engines mainly in the smaller sizes and almost exclusively air-injection engines in the larger ones.

As to the over-all performance of these Diesel oil engines, probably the simplest way of putting the matter in a few words is this: that the thermal efficiency is determined primarily by the pressure at which combustion stops, not when it starts. Other things being equal, the higher the pressure at which combustion is completed, the lower the fuel consumption, and so the higher the thermal efficiency. If combustion is delayed so that it only completes itself at half stroke, with perhaps less than half the highest pressure, then the fuel consumption is bad and the efficiency is low. Therefore, assuming that is so, assuming that engines have the same compression to insure ignition and that through the design the correct timing of combustion is assured, as correct as one could time the cut-off of an old steam gear, then it necessarily would follow that all Diesel engines could have the same thermal efficiency on the indicated horsepower basis, and that is true. That efficiency generally is in excess of 30 per cent. approaching 35 per cent. on the net horsepower basis, a situation that is remarkable in comparison with steam. In addition, the Diesel oil engine performance has a feature of still greater importance, a most amazing thing judged by steam practice, and that is the independence of this very high efficiency with reference to the size of the engine or its horsepower. To get the maximum efficiency with steam, big units are necessary. Central station practice is building 50 000 kilowatt turbines to get the highest efficiency, which corresponds to between 10 and 11 lb. of steam per kilowatt hour. Can that be done in 100 h.p. unit? It cannot. With steam, therefore, the efficiency rises with the horsepower capacity of units and the highest efficiency requires very large units.

With the Diesel engine, this is not so. With the smallest Diesel engine we can get almost exactly as good an efficiency, within 10 per cent. or thereabouts, as with the largest one, and therefore the application of the Diesel engine just necessarily leads into a different rule of practice than is proper for steam, the practice of using a multiplicity of small units in the place of concentrating into a few of large possible size. The combined thermal efficiency of five small Diesel engines of a given capacity is just the same as one large engine of five times the capacity, and that is not true with steam.

Comparing steam and Diesel oil engine efficiencies, one might say that as efficiency rises with size in the case of steam, it tends toward but never reaches the horizontal or constant efficiency line which is characteristic of the Diesel engine, and independent of size. One might also almost say, and it would not be much wrong, that the curve of efficiency of steam engines or turbines regardless of type, plotted vertically, against horsepower per unit plotted horizontally, is almost asymptotic to the horizontal constant efficiency line of the Diesel oil engine, and would meet it at infinity.

On the matter of fuel available, it is important to note that the Diesel oil engine requires a liquid fuel, but that it is capable of burning any liquid fuel regardless of chemical composition or physical properties, except one, and that is, fluidity or viscosity. An oil that will flow through a pump and permit itself to be metered and that will flow through a valve and permit itself to be sprayed, an oil that is sufficiently fluid to permit those things, is a perfectly available fuel. There are places, in different parts of the world, where such a fuel is not obtainable, but where a heavier fuel is obtainable, fuels, for instance, that may, at the temperature of the room, be as solid as vaseline. Those fuels become available by heating, because it is a characteristic property of all of these fuels that by heating they increase their fluidity, but the addition of a heater means another auxiliary part, not to be used except in cases of necessity.

On the other hand, the steam plant with which it is necessary to compare the oil engine, may burn coal or oil. The choice of one or the other may depend entirely or primarily on the cost of the fuel in one or the other forms on a b.t.u. basis. To facilitate such comparison, the chart has been prepared, Fig. 1, Cost of Fuel Per Million B.T.U., Coal and Oil. That is a very useful chart in comparing the coal-burning steam plant with the oil-burning steam plant or the oil-burning Diesel engine, as to the relative values of one fuel compared with another when dollars per ton or cents per gallon are known with calorific values. By this chart and the over-all thermal efficiency, the fuel cost per horsepower hour can be determined.

Next in importance as an item of operating expense is lubricating oil. Many people seem to think that the lubricating oil consumption of the Diesel oil engine is excessively high because they use so much in automobiles. It is not anything of the kind and just two figures, round num-

bers, easily kept in mind, will completely disprove that common comparison. In the small sizes of Diesel engines, the lubricating-oil consumption is better than 2 000 h.p. hrs. per gal. and in the large sizes it is better than 4 000 h.p. hrs. per gal. for all bearings plus the cylinders. Whatever oil is fed to the cylinder of a Diesel engine is gone, lost, not recoverable, but the oil fed to bearings is never lost provided the engine is so designed as to prevent the foul oil from the cylinders coming in contact with the clean oil circulating through its bearings, as is the case with the better ones.

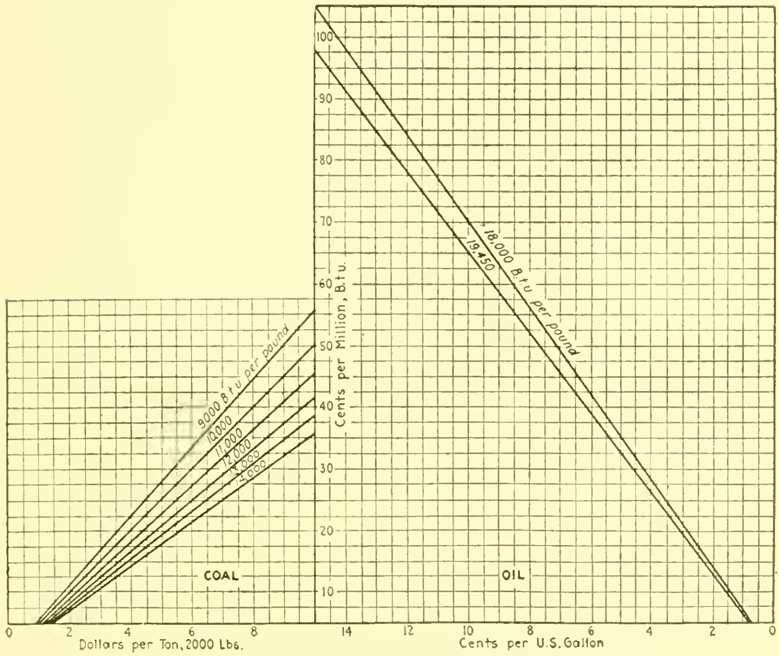

FIG. 1. — FUEL COST PER MILLION B. T. U. COAL AND OIL.

Finally, there are two features to be mentioned in connection with city installation, namely, smoke and noise. On the matter of smoke, attention is called to this universal characteristic of all well-designed, air-injection Diesel engines; that is, they are absolutely smokeless. As a matter of fact, the least little smoke occurring at the exhaust is an indication of derangement and is a warning to fix something, while the absence of the smoke and the clearness of the exhaust is an assurance of good condition. However, in the smaller sizes, and especially with solid injection, and particularly with the two-cycle where the piston is rubbing over the ports, the absolute smokelessness is not quite reached. The combustion may be quite as clean as in a four-cycle engine, but some little lubricating oil rubbed off at the exhaust ports makes a faint haze and a similar haze may result when solid injection replaces air spraying so that in the small

engine the condition of the exhaust is that of a thin transparent or hazy sort of light smoke. Anything more than that is not good and can be corrected, and when everything is just right, complete transparency may result.

Considering noise, two sorts of noise must be noted, the exhaust and the machinery noises. The machinery just naturally makes a sort of

FIG. 2.

rumbling, such as is common to any machine, depending on the size to some extent, also on the foundations and on the echo conditions of the room walls and ceiling. That kind of noise is inevitable to any machine that is not running abnormally slow.

The other sort of noise is the exhaust and on that question it is interesting to note that the exhaust noise can be eliminated quite as completely as on the high class automobile and by the same kind of means. However, when it is necessary to completely eliminate noise to that extent on an oil-engine exhaust, it must be understood that a little back pressure is developed on the engine. Back pressure means a certain loss

in capacity. So that when required to run with absolute noiselessness of the exhaust, some allowance must be made on the rating, as the cost of the silence, but it can be done and quite as effectively, as it is done on a high-class automobile.

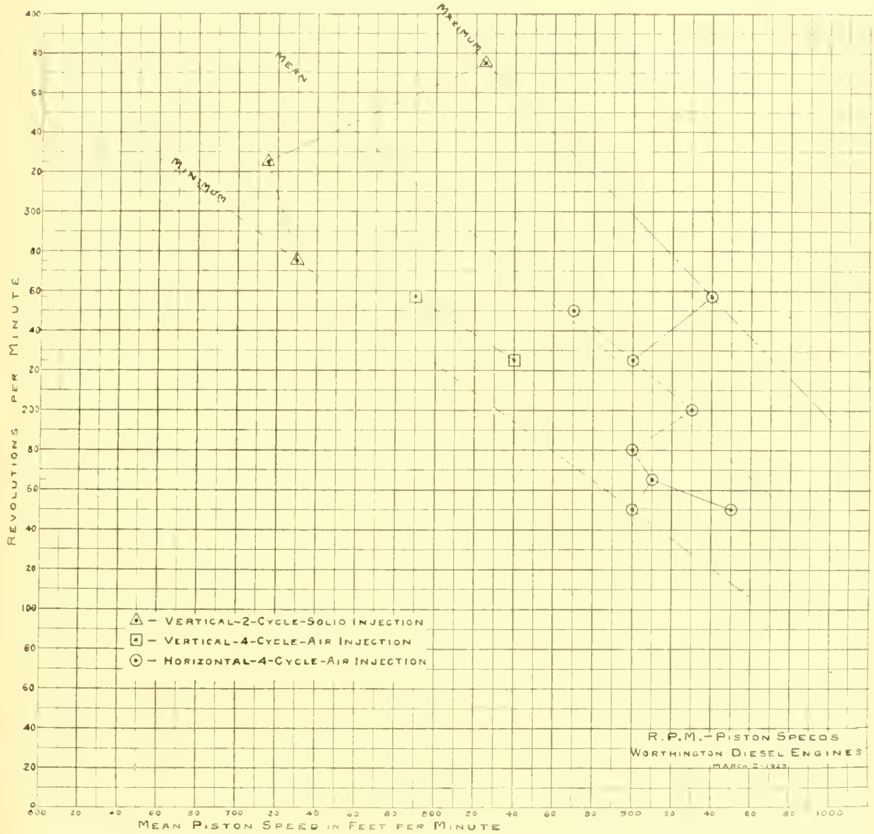

Fig. 3.

At this point it becomes desirable to get down to the matter of the pump relationship to the engine. To make this situation clear and concrete, it is necessary to consider definite machines and the Worthington product is selected. The Worthington oil engines are built in three styles, horizontal and vertical air injection, four-cycle — two styles — and the vertical two-cycle solid injection, the third style. The sizes range from 30 h.p. in 1 cylinder to about 1 100 h.p. in six cylinders and the three lines of sizes are all shown in the chart, Fig. 2. Worthington Diesel Engine Sizes and Speeds. The vertical distances represent the revolutions per minute, the spots represent, each one of them, an actual engine size, the radiating lines through the origin to each of the engine spots indicate what would happen to the horsepower, if the speeds were lowered or raised to

adapt the engine to a particular pump. This chart must be considered in connection with another chart. Fig. 3, Worthington Diesel Engine Sizes, Piston Speeds and r.p.m. which is important when one considers the problem of connecting the engine to the pump, especially a displacement pump. This chart shows the piston speed of the engine horizontally and the r.p.m. vertically. An inclined line has been drawn through the lowest, another one through the highest piston speeds, and a mean line drawn midway to show the general average of practice in the whole line of engines as to the relation of piston speed to r.p.m.

The connection itself, engine to pump, may be direct or it may be by gears, and if one examines the matter closely, it will appear that whether direct connection is feasible or not, depends upon speeds. Speeds will tell just which ones can be directly connected and which cannot, both displacement pumps and centrifugal or screw pumps. It will appear that the great bulk of these pumps cannot be directly connected because it is an accident to find the pump characteristic speed just right for the engine characteristic speed. Therefore, the great majority of this work requires gears.

Gear work falls into two classes, first, the gear down; second, the gear up. Gearing down to lower speeds is no problem, that is an old practice and there are hundreds of such pumps working on all sorts of service. They are typical, for instance, of the oil-pipe-line-pump practice of the West. The gear down is characteristic of the displacement pump and there is available a considerable number of pumps of different types today for gear connection to each one of these engines to absorb its horsepower at different heads and with a correspondingly variable g.p.m. On the gear up, with the centrifugal pump we find this situation: That the experience with steam turbine gears is directly applicable and we can use absolutely the same style of self-contained automatic lubricating gear box that was developed for the other practice, but of course with a different gear ratio. Applying reasonable gear ratios and not going at all beyond the range of proved practice of gear teaching, this range of Diesel oil engine sizes can be used to drive practically the whole line of standardized centrifugal pumps, giving a centrifugal pump for any head within reason and a corresponding g.p.m. to absorb the power of each engine. In the case of the screw pump, which of course it is understood is beautifully adapted to low-head work, there is a little better condition as to direct connection, as speeds conform better, as will appear later, when pumps are considered in more detail.

Further consideration of the water-works and pump phases of this situation of Diesel oil engine use, will be given by three other speakers, each a specialist.

The first topic to be taken up here is the possibility of direct connection of the oil engine and a displacement pump so that r.p.m. or piston speed

will be the same for both pump and engine. This will be presented by three of my associates in the Worthington Organization, first, Mr. Rodney D. Hall, Mgr. of the Water Works Department, will present the case for the Direct Connection of Diesel Engines to Displacement Pumps of Equal R.P.M. or Piston Speed. He will be followed by Mr. H. M. Chase, Engineer of the Deane Works, Holyoke Mass., who will explain the situation with regard to Displacement Pumps Gear Driven By Diesel Engines At Reduced R.P.M. and by Mr. Max Spillmann on Centrifugal and Screw Pumps Driven by Diesel Engines, Direct Connected or Through Gears. Finally Mr. Hall will close with a general comparison of Steam and Diesel Water Works.

Direct Connection of Diesel Engines and Displacement Pumps.

BY RODNEY D. HALL.*

For many years I have been associated with the work of the Snow-Holly Works of the Worthington Corporation, located in Buffalo, N. Y., which has built for some thirty years steam reciprocating displacement pumping machinery in capacities of from three million to forty million gallons in twenty-four hours, in both horizontal and vertical types. Some twenty years ago the Snow horizontal steam cross-compound type of pumping engine was developed and it has given very successful service. When, later on, these works began building horizontal 4-cycle air-injection Diesel engines up to 600 h.p., the possibilities of making such engines into pumping engines were given considerable study, some of the results of which will be reported.

The subject at the present time is the reciprocating displacement pump, in types and sizes suitable for direct connection to Diesel engines. The drawing, Fig. 4, shows a Worthington horizontal twin 150 h.p., oil, engine-driven pumping engine of the opposed type, size 20 in. x $8\frac{1}{4}$ in. x 33 in. Each side of the unit has a 150 h.p., Diesel power cylinder attached to one end of each of the two main frames. At the opposite end of the frame is an outside center packed plunger water end of the same construction as our most modern steam pumping engine. This pump runs at 165 r.p.m. at rated capacity, a speed entirely feasible, as has been demonstrated by the Unaflow pumping engine. The Porter Avenue experimental pumping engine at Buffalo was operated successfully up to 200 r.p.m., and when it got down to 165 revolutions, it seemed as if it were running at a slow speed. There was no difficulty in handling the water at these speeds with the Decrow Unaflow pump valve, because the valve construction was such and the valve area sufficient, to keep the speed of the water within the limits of conservative water-works practice.

* Manager Water Works Department, Worthington Pump and Machinery Corp.

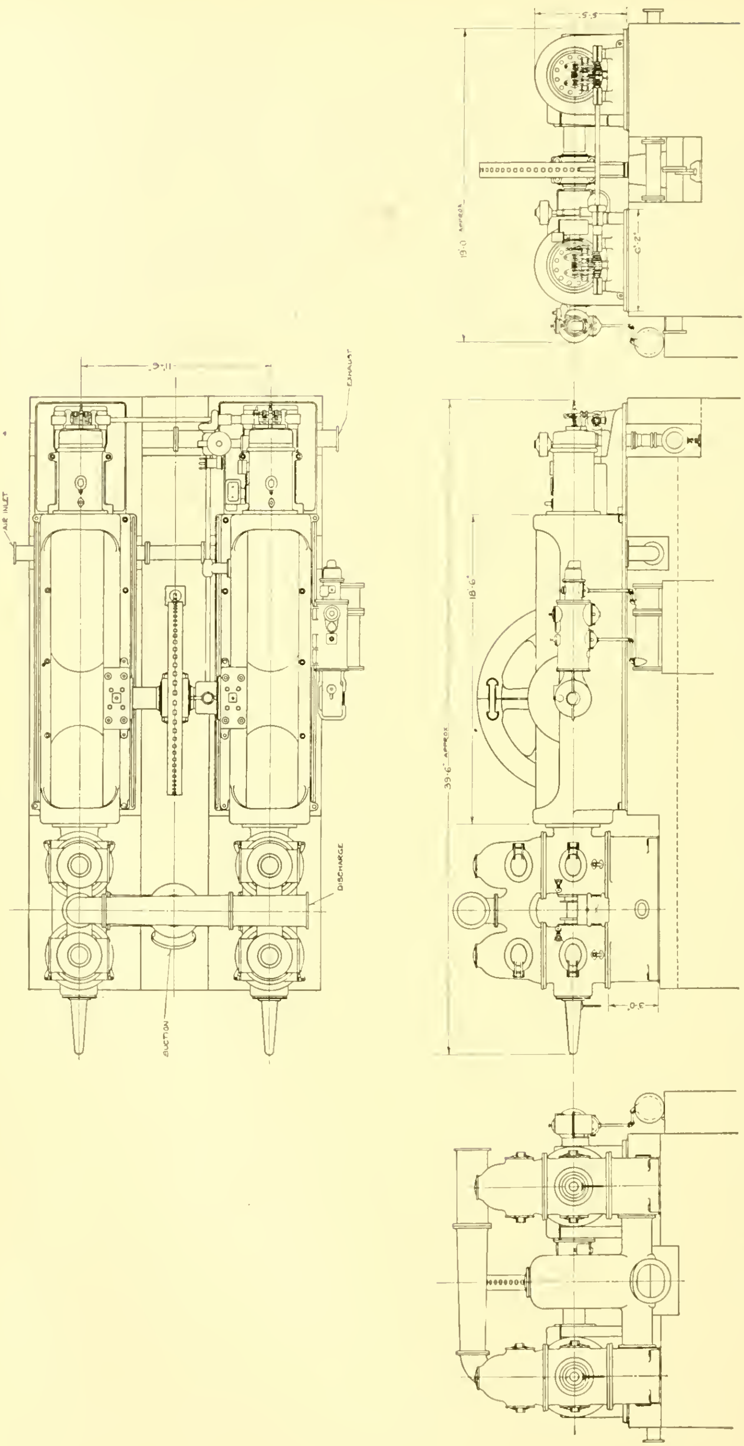

FIG. 4. — WORTHINGTON HORIZONTAL DIESEL ENGINES DIRECT CONNECTED TO DISPLACEMENTS PUMPS — OPPOSED ARRANGEMENT — SAME PISTON SPEED AND R.P.M.

In Fig. 5 there is shown another adaptation of a 150 h.p. single-cylinder Worthington horizontal Diesel oil engine connected by means of a crank to a displacement pumping engine having one double-acting plunger. The oil-engine prime mover has a 33-in. stroke; the pump that it drives has

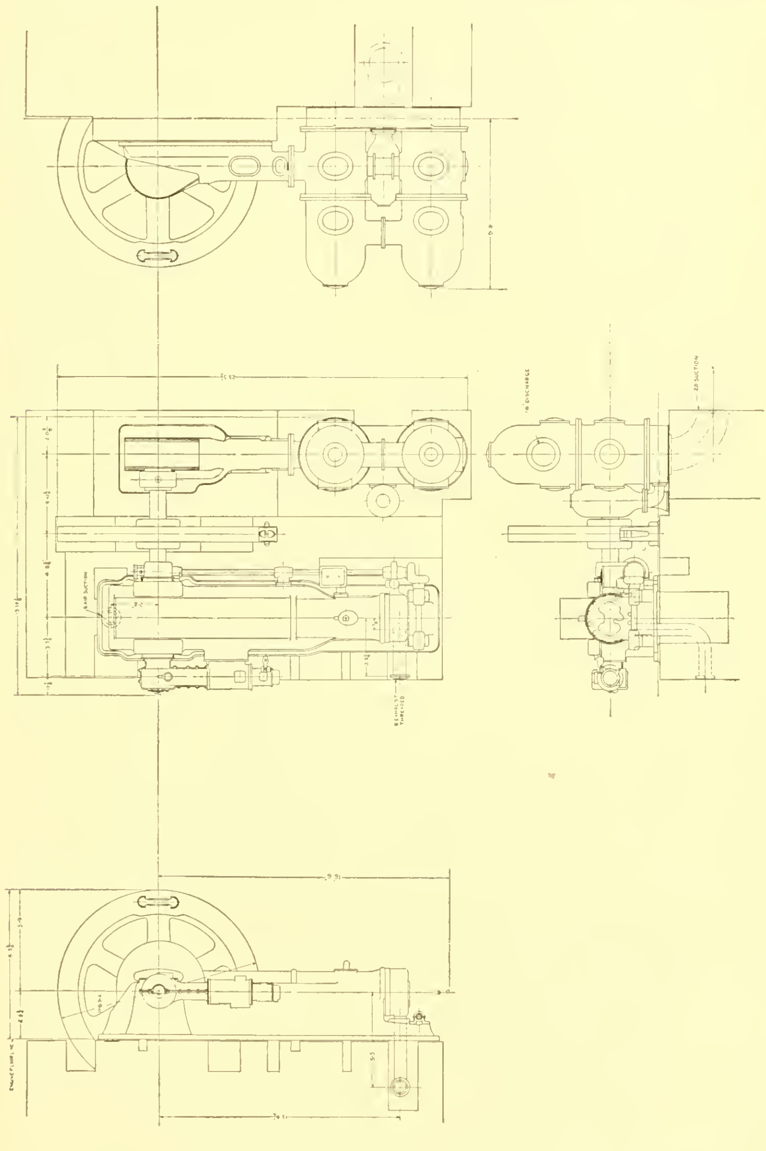

Fig. 5. — Worthington Horizontal Diesel Engine Direct Connected to Displacement Pump — Twin Arrangement — Same R.P.M. and Different Piston Speeds.

a 21-in. stroke. The number of revolutions in each case is the same (165 r.p.m.) but the piston speed of the pump, due to its shorter stroke, is approximately 64 per cent. of the oil-engine piston speed. This 21-in.-stroke combination takes the same fluid end as the experimental Unaflow pumping engine which many of those present saw at Buffalo. There are

not many sizes and styles of oil engines that have suitable speeds for such direct connection to displacement water ends.

In water-works practice it is necessary to convert horsepower into terms of capacity and pressure, and, to make such conversion easy, the Chart Fig. 6 has been worked out. The limits shown by this chart are

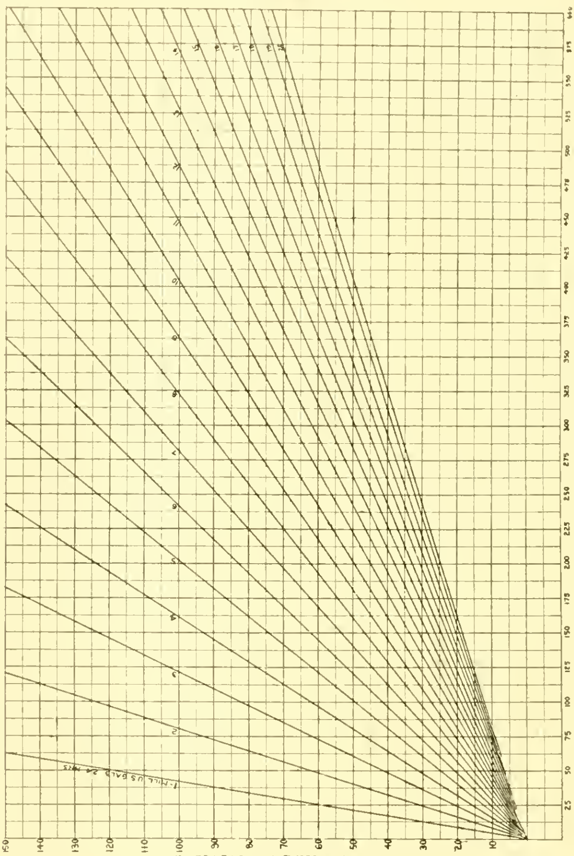

Fig. 6. — Conversion Chart — H.P., G.P.M. and Head.

water pressures up to 150 lb. per sq. in. (as high as would be used in normal water-works practice), and horsepower up to 600, which would be a suitable water end load for a 750 h.p. engine. Six hundred useful water horsepower is also about the maximum point for reciprocating pump reduction gears. On water ends of the reciprocating type there are available developed designs up to 20 000 000 gal. capacity. By reference to the chart, it will be seen that 20 000 000 U. S. gal. of water in 24 hr. against approximately 74-lb. water pressure, is equivalent to 600 water h.p. All of the Snow-Holly standard water ends are strong enough for 150-lb. working pressure.

Displacement Pumps Gear Driven by Diesel Engines at Reduced R.P.M.

BY H. M. CHASE.*

The Diesel oil engine, at a fixed suitable speed for it, has but one variable, that is the horsepower, and any conditions that come within the horsepower capacity may be satisfied, providing that the proper selection is made of the pump. The pump must be selected to satisfy the two vari-

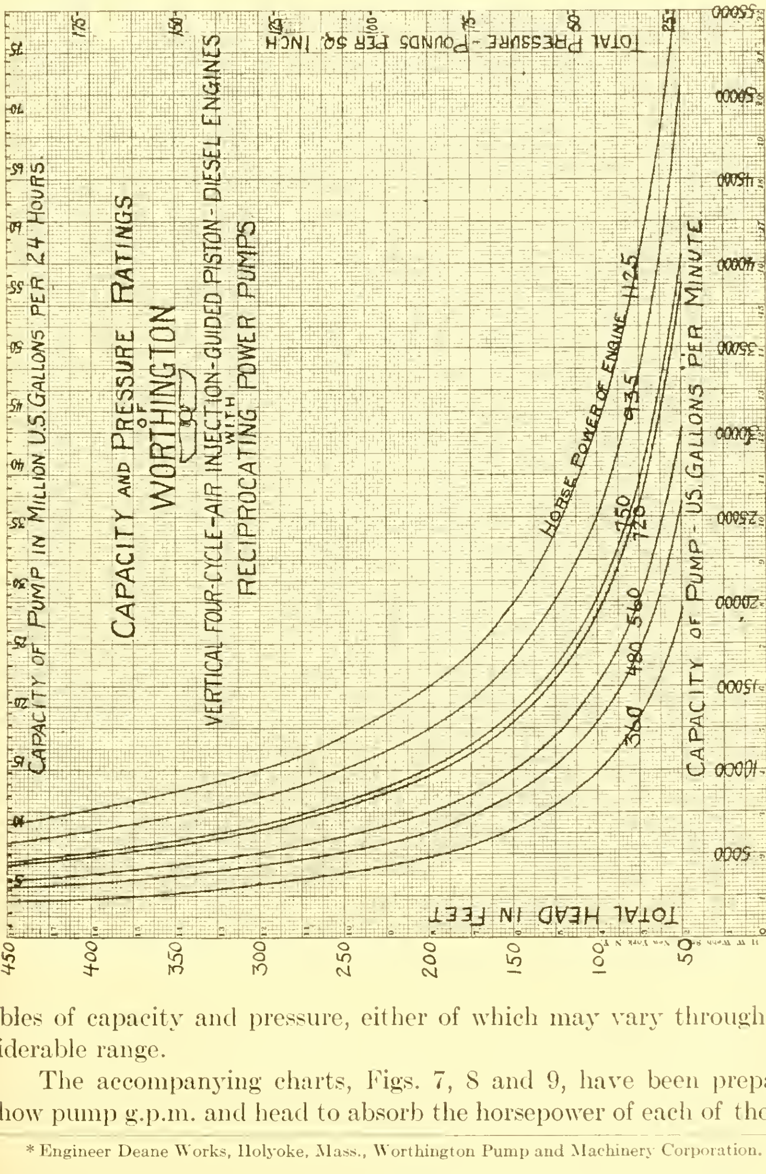

Fig. 7. — Displacement Pump G.P.M. and Head to Absorb the H.P. of Worthington Four-Cycle Air-Injection Diesel Engine.

ables of capacity and pressure, either of which may vary through a considerable range.

The accompanying charts, Figs. 7, 8 and 9, have been prepared to show pump g.p.m. and head to absorb the horsepower of each of the stand-

* Engineer Deane Works, Holyoke, Mass., Worthington Pump and Machinery Corporation.

ard sizes of Worthington Diesel Engines. Fig. 7 covers the range of the vertical four-cycle, air-injection type; Fig. 8 that of the vertical two-cycle solid-injection engines, and Fig. 9 the horizontal four-cycle, air-injection type. The curved lines represent the horsepower of engine and in the computations on which the charts are based, allowance has been made for the

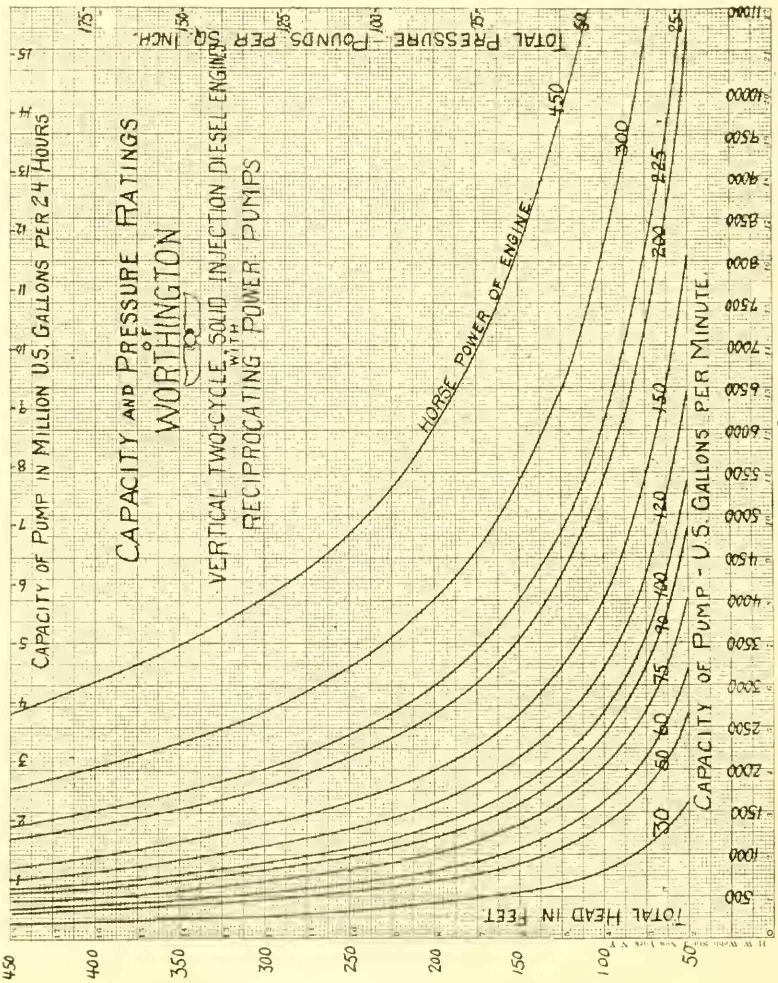

Fig. 8. — Displacement Pump G.P.M. and Head to Absorb the H.P. of Worthington Verticle Two-Cycle, Solid-Injection Engine.

efficiency of the pump at 85 per cent. and also allowance for operation of the engine at 80 per cent. of its rated horsepower, to allow ample margin for a change of conditions that may require power in excess of that anticipated.

The vertical lines on the chart represent capacity in gal. per min. or gal. per 24 hr., and the horizontal lines represent total head conditions in feet, or in lb. per sq. in. pressure. Thus, having determined the capa-

city required and the total head, including, of course, suction lift and pipe friction, against which it must be pumped, a direct reading on the chart will indicate the size of Worthington engine suitable for the service.

The charts indicate the wide range of conditions that can be met economically by standard Diesel oil engines. At 100 lb. pressure there are

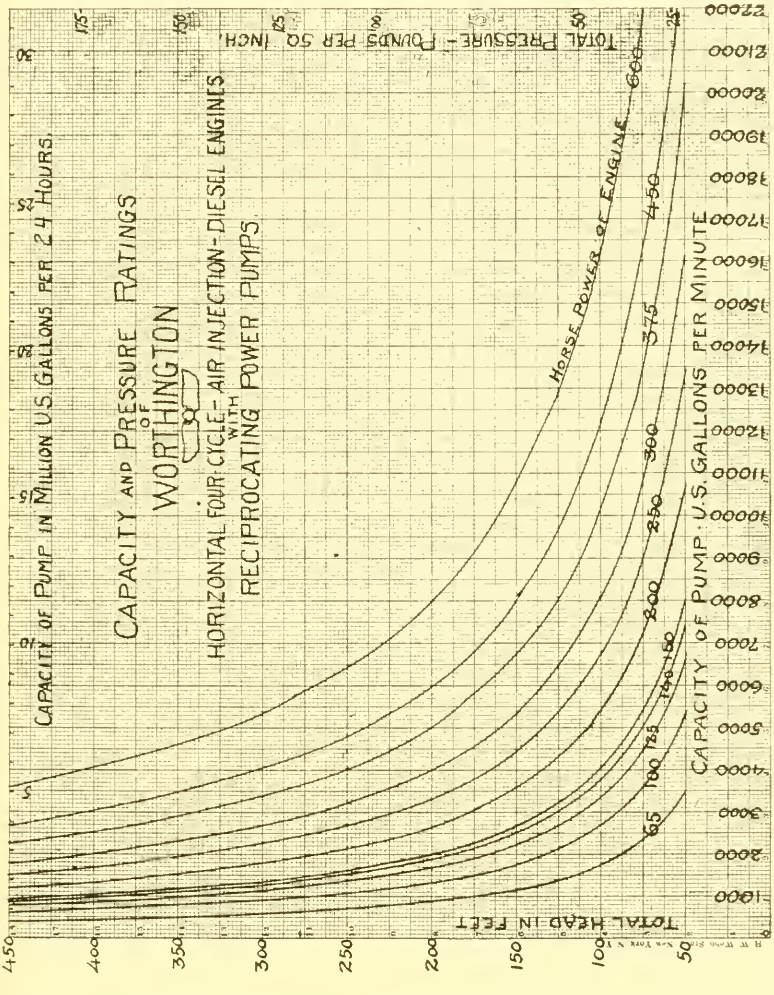

Fig. 9. — Displacement Pump G.P.M. and Head to Absorb the H.P. of Worthington Horizontal Four-Cycle, Air-Injection Diesel Engine.

engines suitable for capacities of half a million gallons to twenty million gallons per day, and at 200-lb. pressure there are engines good for anything between one quarter million to ten million gallons per day. Examination of the charts will show that for practically any combination of conditions within this range there is an engine that is the right size. It does not become necessary to select an engine too small or too large for the work in order to utilize manufacturers' patterns, because the Worthington standard oil-engine lines so completely cover the range of requirements.

The pumps now available for service in such an installation are of both the vertical and the horizontal type, selection between which will depend upon the local conditions. For the smaller capacity units the vertical triplex pump is usually selected. This type is available in any capacity from a 7 in. x 10 in. for one quarter million gallons per 24 hours, to a 16 in. x 16 in. for three million gallons.

Sixteen complete power ends 10, 12, 14 and 16-in. stroke for net plunger loads from 4 000 lb. to 36 000 lb., and an almost limitless number of water ends suitable for combination therewith, permit the construction of a pump suitably proportioned for any combination of conditions within the range mentioned above for capacity, and for any pressure requirements of water-works service.

The speed of the vertical triplex pump usually lies between 35 and 60 r.p.m. of the crank shaft, and between 60 and 120 ft. per min. plunger travel. The Diesel engine speeds vary between 150 and 375 r.p.m. Thus the maximum variation between speed of engine and speed of pump will not exceed a ratio of about 10 to 1. A single reduction of standard type spur or herringbone gears will meet any of the requirements at a rim speed capable of quiet operation. Such pumps, whether driven by belt, water wheel, electric motor, or engine, have at least one reduction of gears between the crank shaft and the jack shaft. The Diesel engine drive, therefore, introduces no complications. A set of gears is selected which will give the crank shaft of pump the proper speed, and give the jack shaft a speed the same as that of the engine. Connection between engine shaft and jack shaft of pump is made by means of a flexible coupling, or a friction cut-off coupling. In any case the pump is provided with a by-pass between the discharge and suction allowing release of the water load when starting. The engine will readily start with the friction load of the engine and pump as is required where a flexible coupling is used, but if it is necessary for special conditions to eliminate the load due to friction of the pump when starting, the friction cut-off coupling may be used.

One of these, a vertical triplex pump of approximately one half million gallons capacity, is shown in Fig. 10, driven by a 40 h.p. single cylinder vertical two-cycle solid-injection Diesel engine. Another one of larger size, 16 in. x 14 in. of four million gallons capacity is shown in Fig. 11 driven by a 150 h.p. two-cylinder vertical engine of the two-cycle, solid-injection type.

For still larger capacity requirements the horizontal type of pump either duplex or triplex, is better adapted on account of its greater stability, and the permissible elevation of the jack shaft being such as to allow a common foundation level for pump and engine.

The pumps are built in a great variety of patterns of 12-18-24 and 36-in-stroke and operated at a speed from 25 to 50 r.p.m. of crank shaft giving a very moderate plunger speed of from 80 to 300 ft. per min. Here too the relative speeds of engine and pump are such as to allow a single reduc-

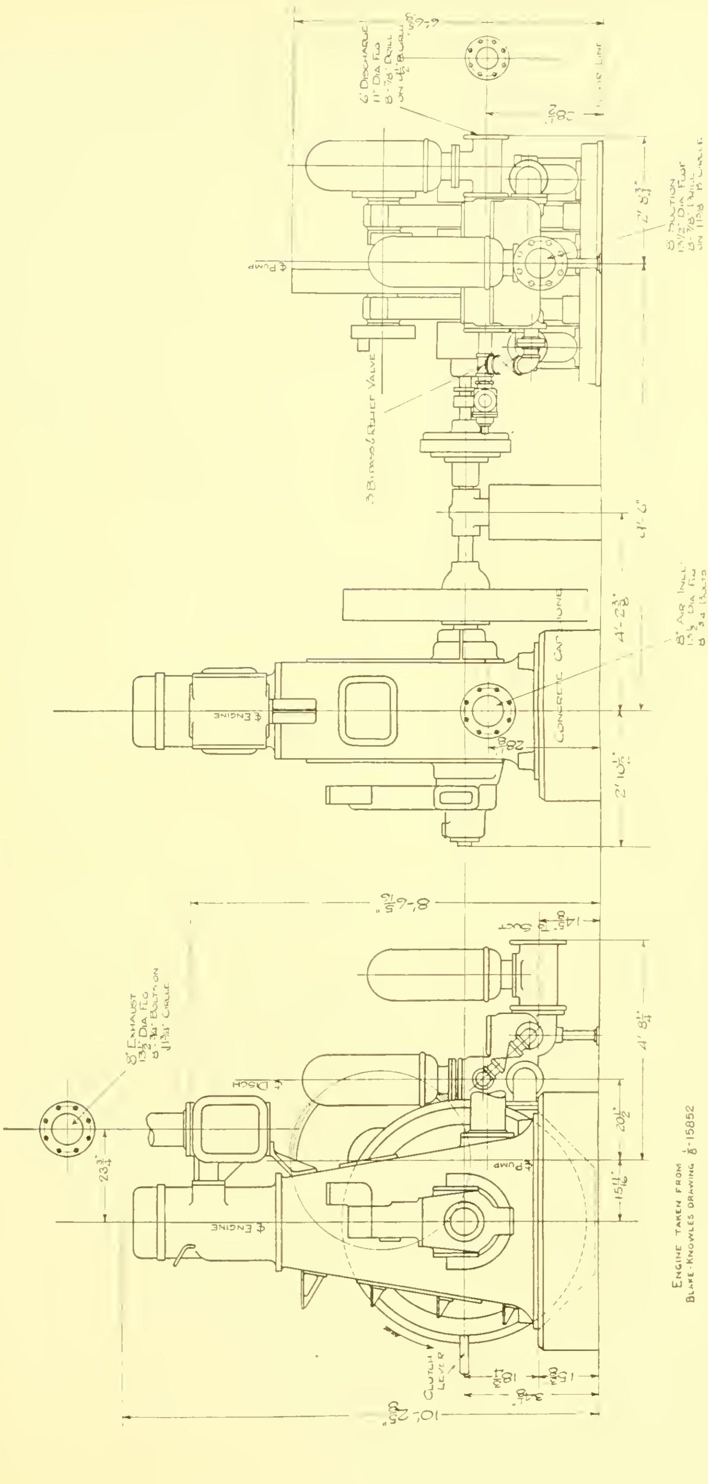

FIG. 10. — VERTICAL TRIPLEX PUMP, HALF MILLION GALLONS, GEAR DRIVEN BY 40-H.P. WORTHINGTON VERTICAL SOLID-INJECTION TWO-CYCLE OIL ENGINE.

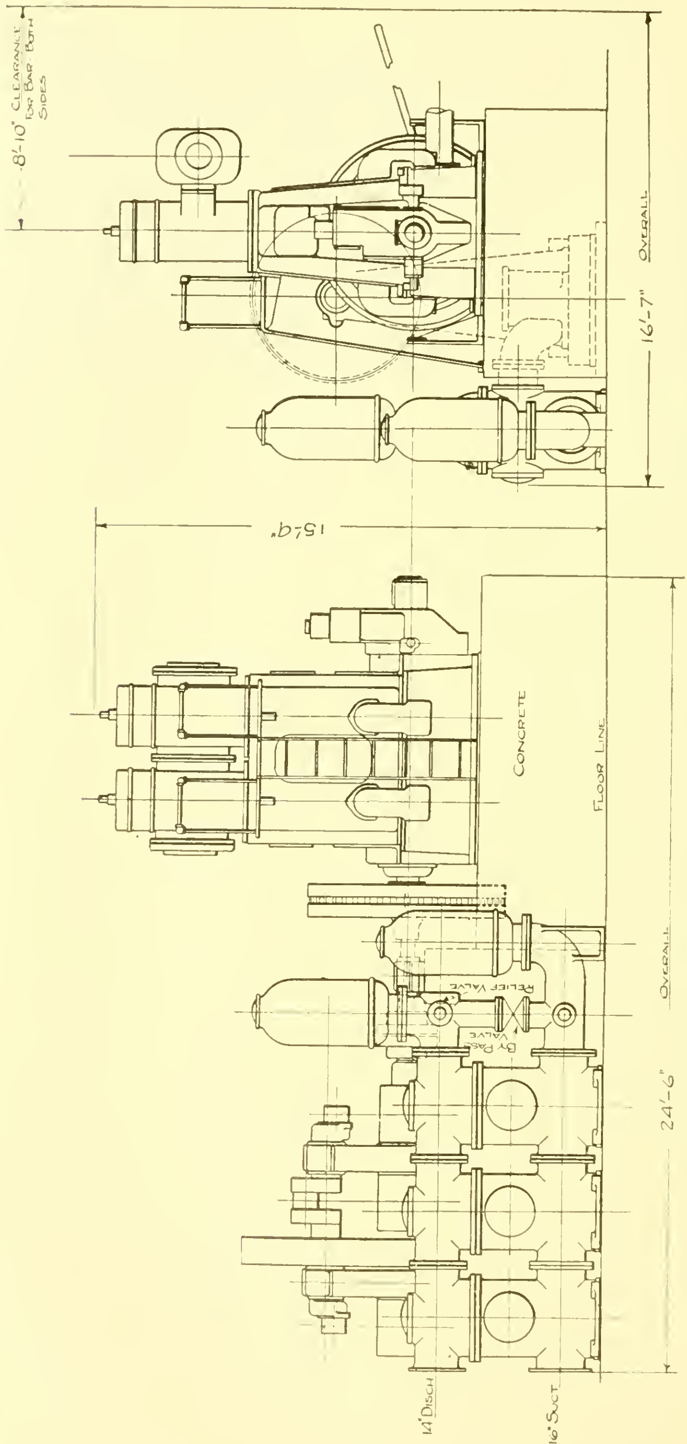

Fig. 11. — Vertical Triplex Pump, Four Million Gallons, Gear Driven by 150-H.P. Vertical Solid-Injection, Two-Cycle Worthington Oil Engine.

tion of spur or herringbone gears, and connection by means of a flexible coupling or friction clutch. Sizes from 6 x 12 duplex having a capacity of one-third of a million gallons per day, up to a 21 x 36 triplex giving twenty million gallons per day are available from existing patterns, and the variety

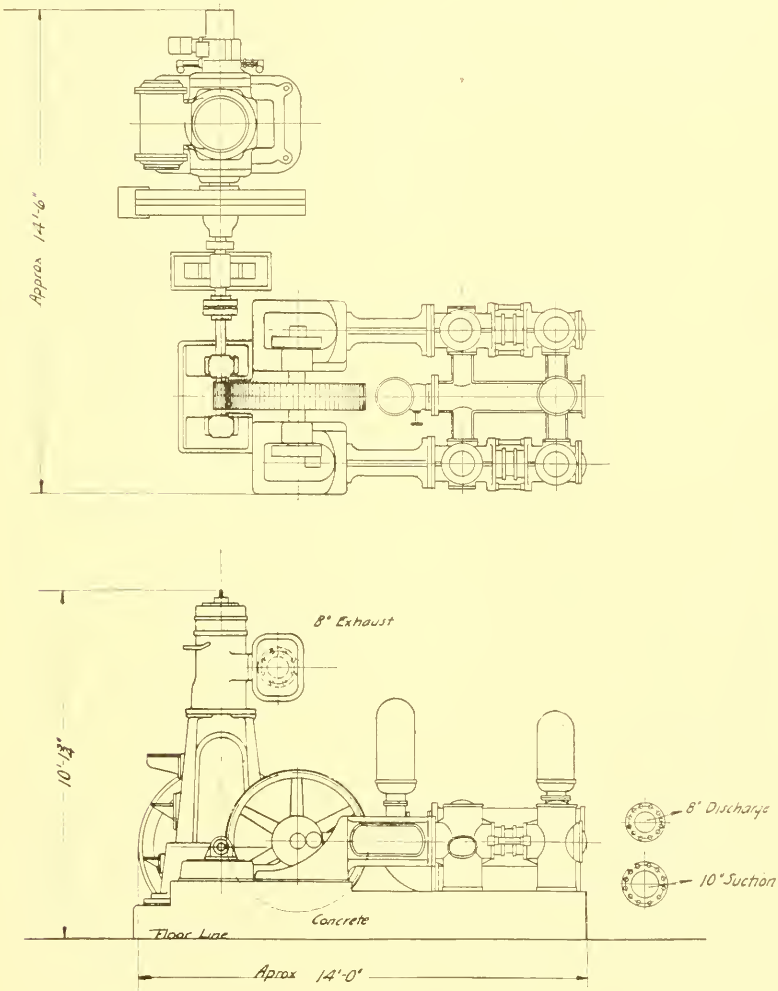

Fig. 12. — Horizontal Duplex Pump, Half Million Gallons, Driven by 50-H.P. Vertical Worthington Two-Cycle, Solid-Injection Oil Engine.

of power ends and water ends permit of combination to produce a pump correctly proportioned for any conditions of services within the above limits.

Typical arrangements of such units are shown in the illustrations: Fig. 12 shows an 8 in. x 12 in. horizontal duplex pump of one-half million gallon capacity connected to a single cylinder 50 h.p. vertical two-cycle,

solid-injection Diesel Engine; Fig. 13 a 14-in. x 18 in. horizontal duplex pump of three million gallon capacity, driven by a 150 h.p. two-cylinder vertical two-cycle, solid-injection Diesel Engine; Fig. 14 a 15 in. x 36 in.

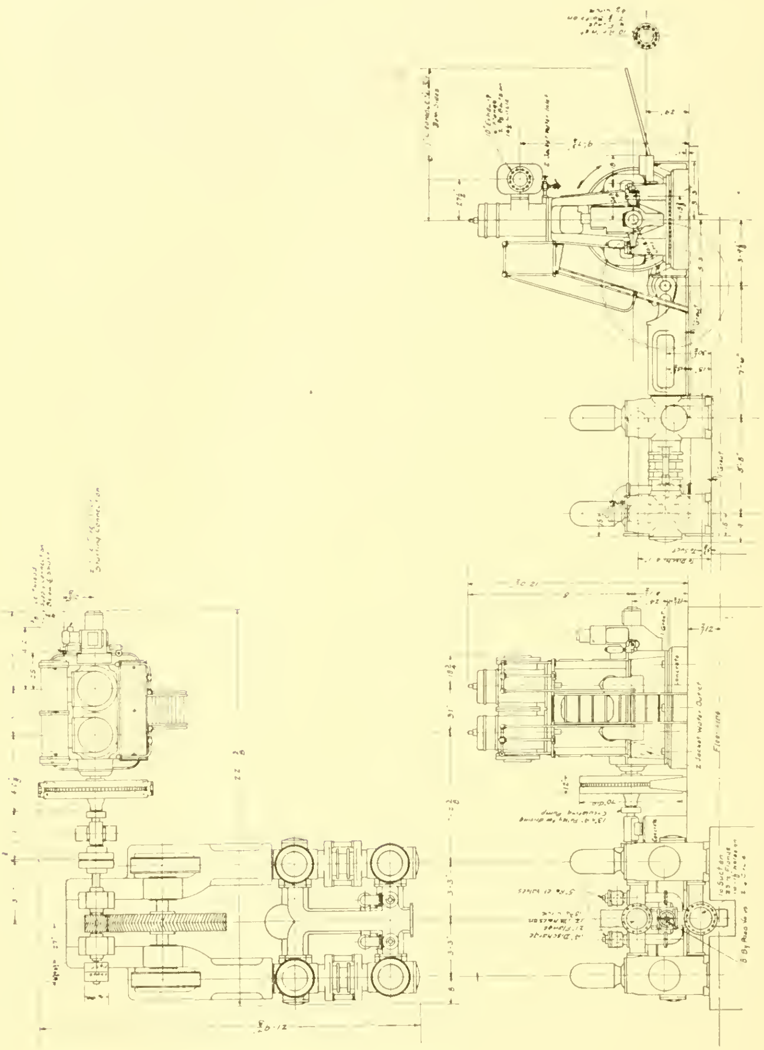

Fig. 13. — Horizontal Duplex Pump, Three Million Gallons, Gear Driven by 150-H.P. Worthington Oil Engine.

horizontal triplex pump of ten million gallons capacity, driven by a 750 h.p. four-cylinder vertical four-cycle air-injection engine.

The cuts show clearly the compactness and simplicity of the complete plant which is a feature of this type of installation.

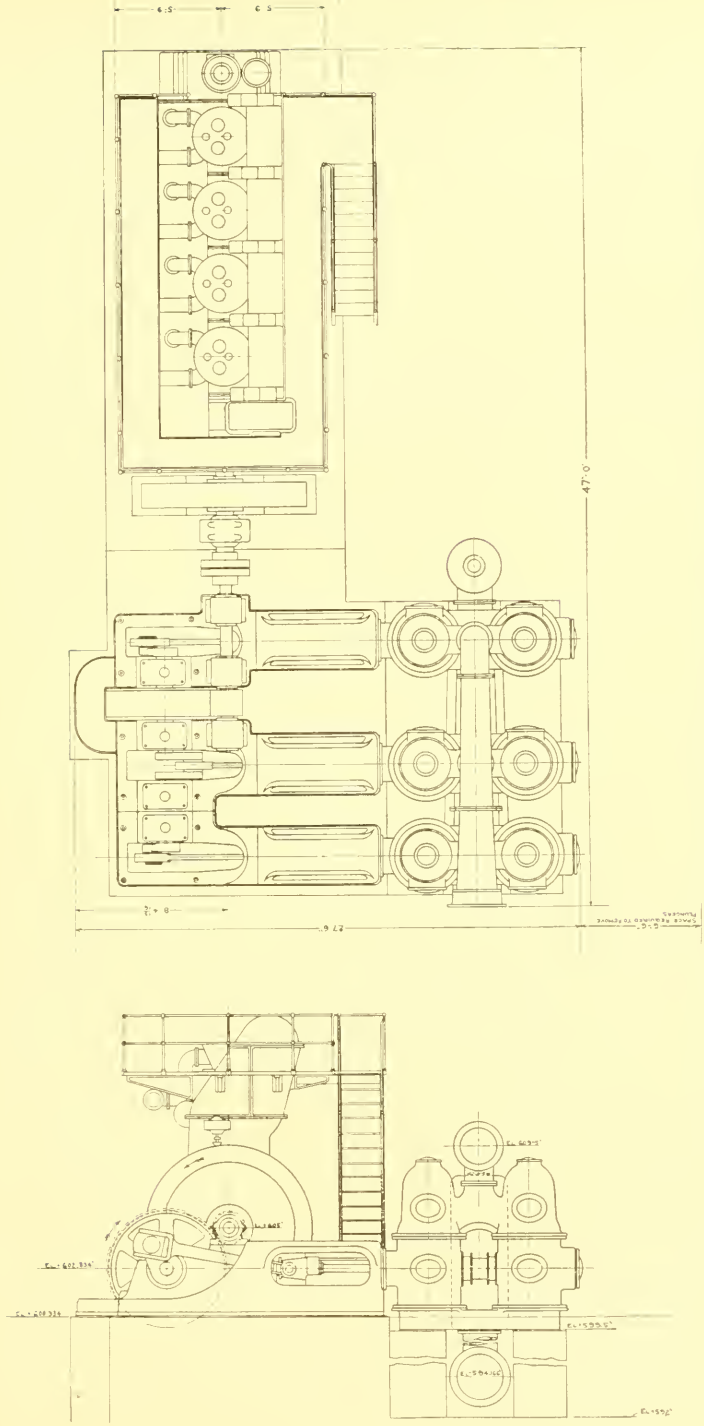

FIG. 14. — HORIZONTAL TRIPLEX PUMP, TEN MILLION GALLONS, GEAR DRIVEN BY 750-H.P. WORTHINGTON OIL ENGINE, FOUR-CYCLE AIR INJECTION.

Centrifugal Pumps for Diesel Engine Drive.

BY MAX SPILLMANN.*

The limitations of the centrifugal pump to raise water economically are chiefly governed by the available speed, revolutions per minute. Such speeds as the commercial Diesel engine develops are suitable for pumping against low and medium heads within certain limits of capacity.

To obtain higher working pressures, several means are available.

1. To operate several single-stage pumps in series, at engine speeds.
2. To interpose between driving engine and pump a speed-increasing gear.
3. A combination of the two above methods.

The final selection must be directed toward obtaining maximum efficiency, minimum of floor space and minimum of investment.

The modern herringbone gear can be successfully used for a speed ratio of $1:5\frac{1}{2}$ in single reduction. This brings within the range of Diesel engine drive the complete line of standard centrifugal pumps designed for alternating current motor drive with speeds of 1 800 r.p.m., 1 200 r.p.m., 900 r.p.m., etc.

For low and medium heads it is possible either to drive direct by using the low-speed type of pump formerly developed for steam-engine drive, or to select a high speed-pump with speed-increasing gear.

When the pumping heads are very low, 3 ft. to 15 ft., it is often found that the Diesel engine speeds are too high for direct connection to the centrifugal pump. For such conditions the screw pump takes its place. By careful study of the problem, this type of pump has reached a development where its efficiency is equal and even superior to the centrifugal type.

To illustrate the foregoing, three curves, E-4017, 4018 and 4019, Figs. 15, 16 and 17, have been prepared showing centrifugal pump and engine sizes for working heads between 5 ft. and 500 ft., and capacities within the horsepower range of the respective Diesel engines.

For example, assuming a pumping condition of 1 800 g.p.m. against 140 ft. head, curve Fig. 4019 leads to the selection of an 8-in. single-stage pump driven by a 100 h.p. engine whose normal speed is 325 r.p.m., the pump speed is 1 450 r.p.m., pump efficiency 76 per cent. and gear efficiency $98\frac{1}{2}$ per cent. In many cases a great number of alternates may be made not shown on these curves, which only include pumps such as are commonly carried in stock.

Direct connection is suitable for heads from 30 ft. with minimum size engine (30 h.p.) to heads of 75 ft. with large size engine (450 h.p.) without resorting to multi-stage pumps.

Unless a special non-overload governor is provided for, centrifugal pumps should be selected with such characteristics that the driving engine

* Works Engineer, Worthington Works, Harrison, N. J., Worthington P. & M. Corporation.

cannot be overloaded at constant speed when the pump is working over a range of head as may be met in service. The pump design, therefore, does not in any way differ from the one which is selected in alternating current-induction motor drive. When a gear is used it will be mounted on a

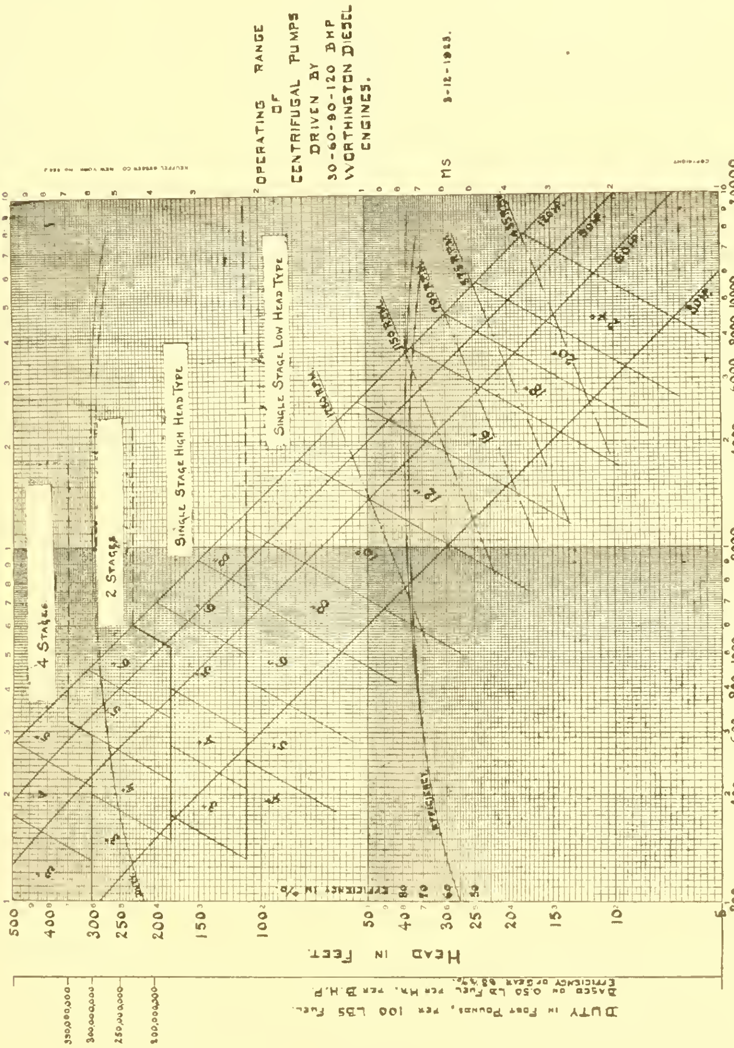

Fig. 15.

common base plate with the pump. Flexible couplings are essential with gear drive. For direct drive either rigid or flexible couplings may be used.

Valuable experience has been gained during the last few years in the design of speed-increasing gears. New gear-cutting machinery has been evolved and limits for allowable tooth pressure and pitch-line speed were

determined; also proper methods of automatic lubrication. As a consequence the product now available is as dependable as the engine and pump, and the noise which was observed in earlier designs has been suppressed.

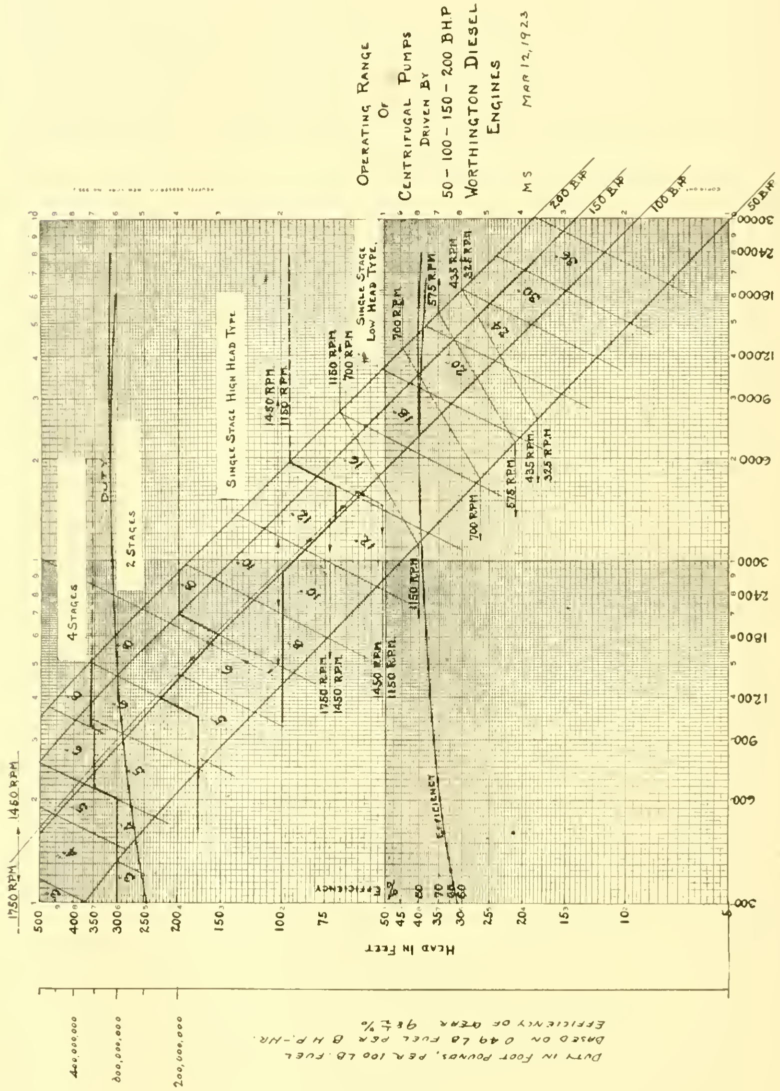

FIG. 16.

In selecting gears consideration is given to the variation in torque resulting from the use of single or multiple cylinders and the flywheel effect of the engine.

The characteristics of the ordinary centrifugal pump are too well known to require any special mention here. It might be of interest here,

however, to give some data from a test of a Diesel engine screw pump which was recently obtained in the hydraulic laboratory of the Worthington Works at Harrison, N. J. This unit consisted of a 36-in. screw pump direct connected to a 75-h.p. single cylinder 275 r.p.m. Worthington Diesel

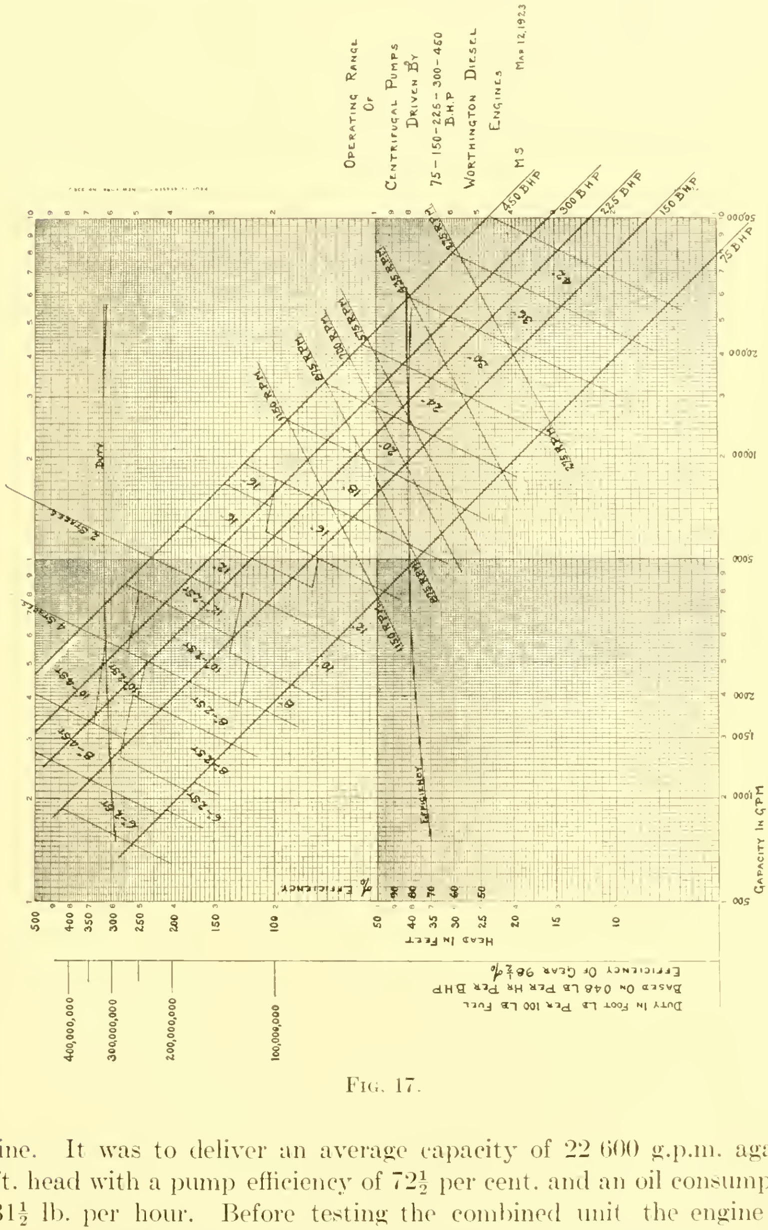

Fig. 17.

engine. It was to deliver an average capacity of 22 600 g.p.m. against $7\frac{1}{2}$-ft. head with a pump efficiency of $72\frac{1}{2}$ per cent. and an oil consumption of $31\frac{1}{2}$ lb. per hour. Before testing the combined unit the engine was tested with a water brake and the pump with a calibrated electric motor. Both pump and engine easily met their guarantees. The test of the com-

bined unit was of 72-hr. duration, during which observations were made of capacity, head, revolutions per minute and total fuel used.

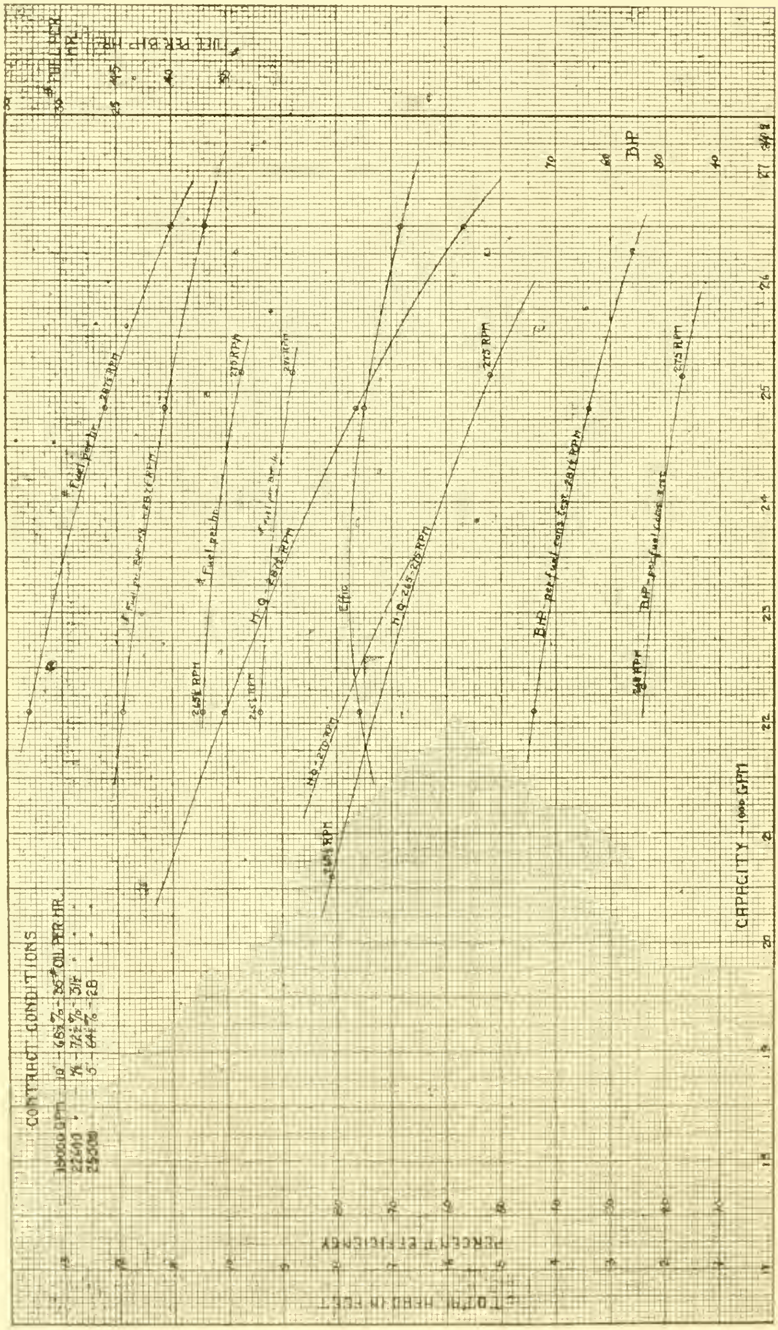

Fig. 18. — Test of Worthington 36″ Screw Pump Direct Connected to Single-Cylinder Worthington Diesel Engine.

The attached curves, Fig. 18, give the results at different speeds and clearly show the remarkable economy obtained both with the engine and pump, which in itself is so extremely simple an installation, as shown in Fig. 19. Some additional pumps and Worthington Diesel two-cycle

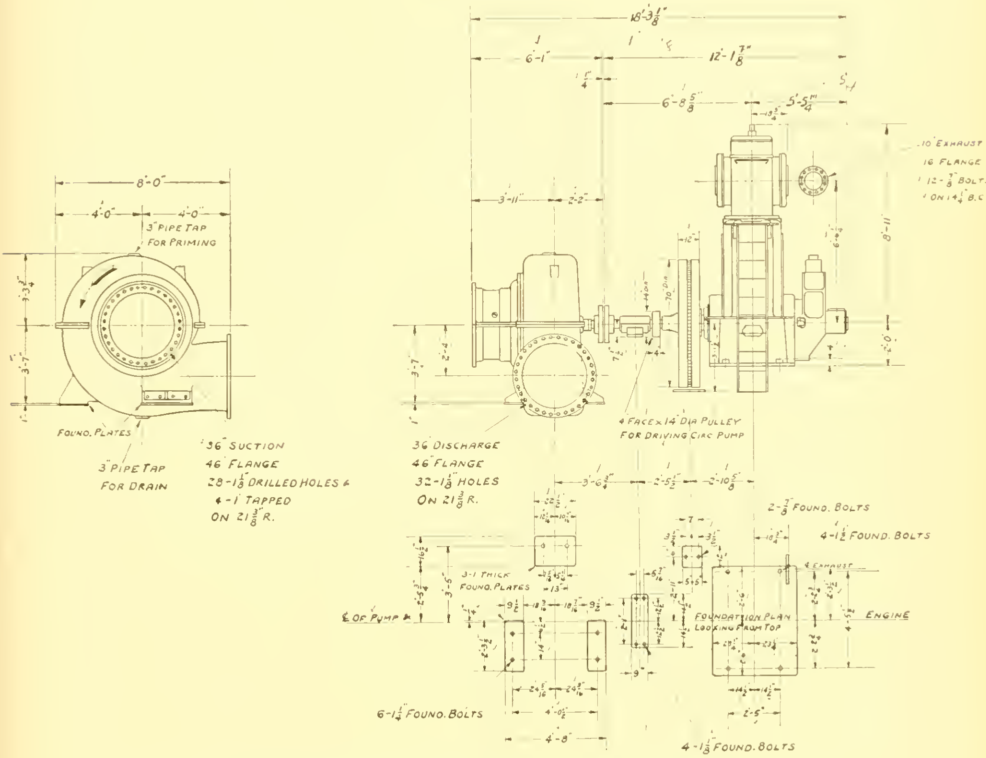

FIG. 19. — WORTHINGTON SCREW PUMP 36" DIRECT CONNECTED TO SINGLE-CYLINDER WORTHINGTON OIL ENGINE.

solid-injection vertical engines are shown in Figs. 20-23. The first of these, Fig. 20, shows a two-cylinder engine direct connected to a 48-in. screw pump; Fig. 21, a three-cylinder engine gear connected to a 72-in. screw pump; Fig. 22, a four-cylinder engine gear connected to an 80-in. screw pump; and Fig. 23, a four-cylinder 300 h.p. engine gear connected to a three-stage, single-suction Jeansville Worthington centrifugal pump.

Due to its low starting torque, the Diesel engine-driven centrifugal pump is always ready for service and requires no clutch couplings or similar devices for starting.

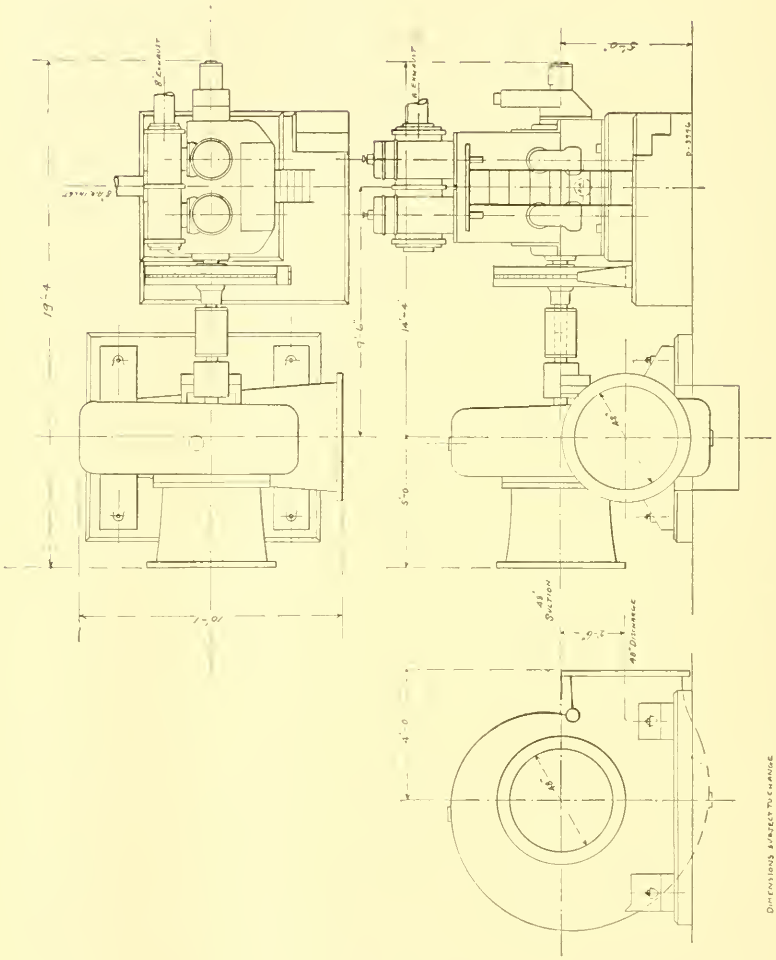

FIG. 20. — Two-Cylinder Worthington Oil Engine Driving 48" Screw Pump.

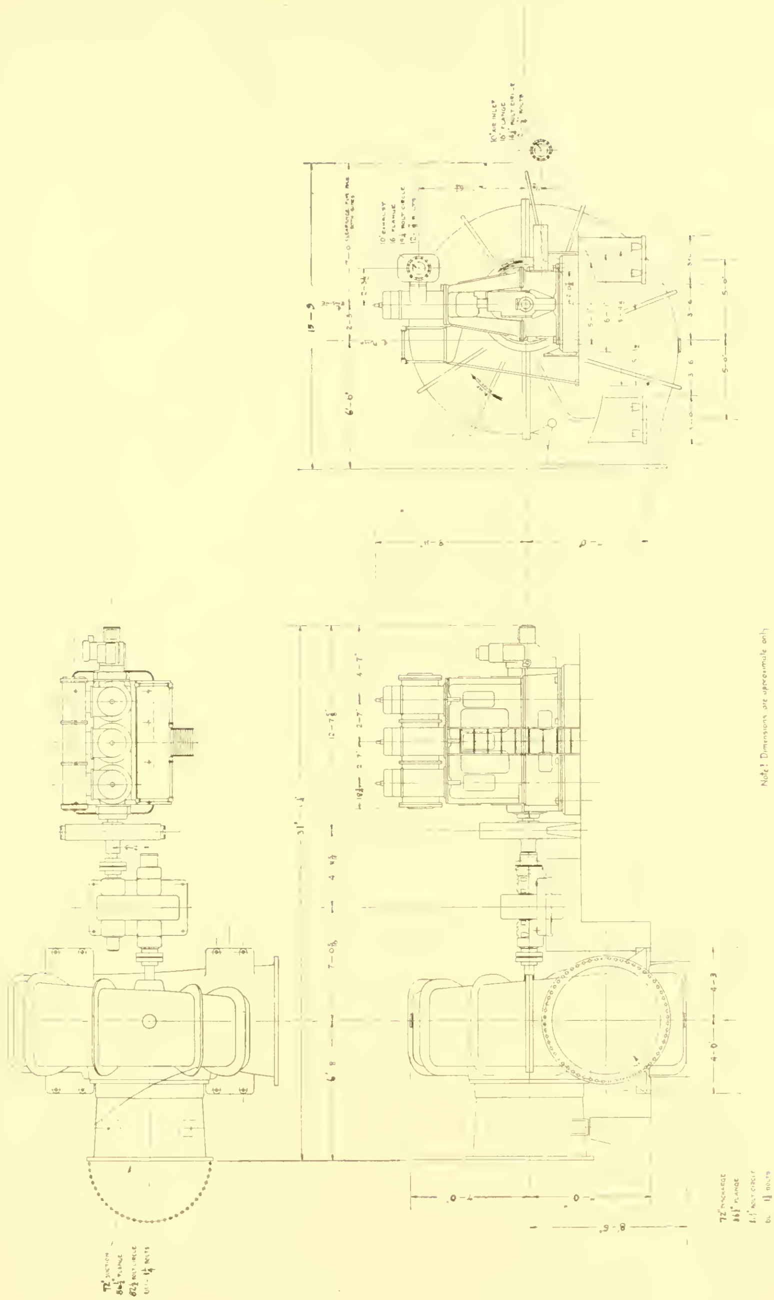

FIG. 21. — THREE-CYLINDER WORTHINGTON DIESEL ENGINE, GEAR DRIVING 72" SCREW PUMP.

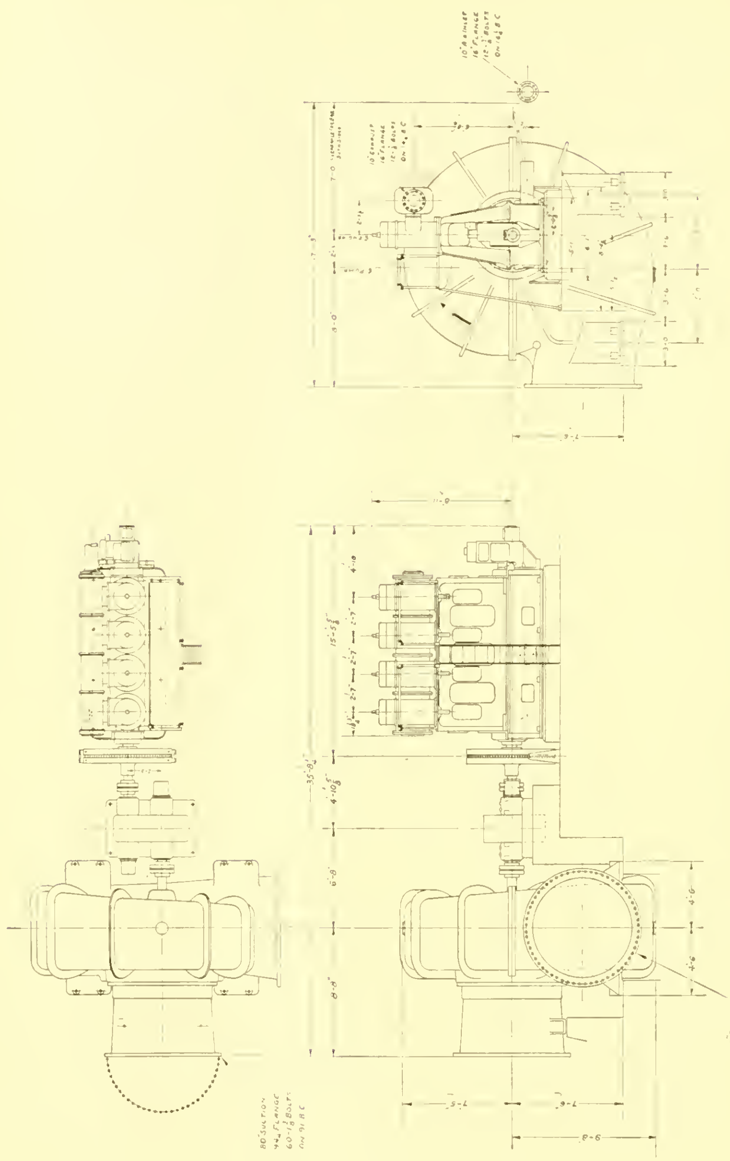

FIG. 22. — GEAR DRIVEN 80" SCREW PUMP CONNECTED TO FOUR-CYLINDER WORTHINGTON OIL ENGINE.

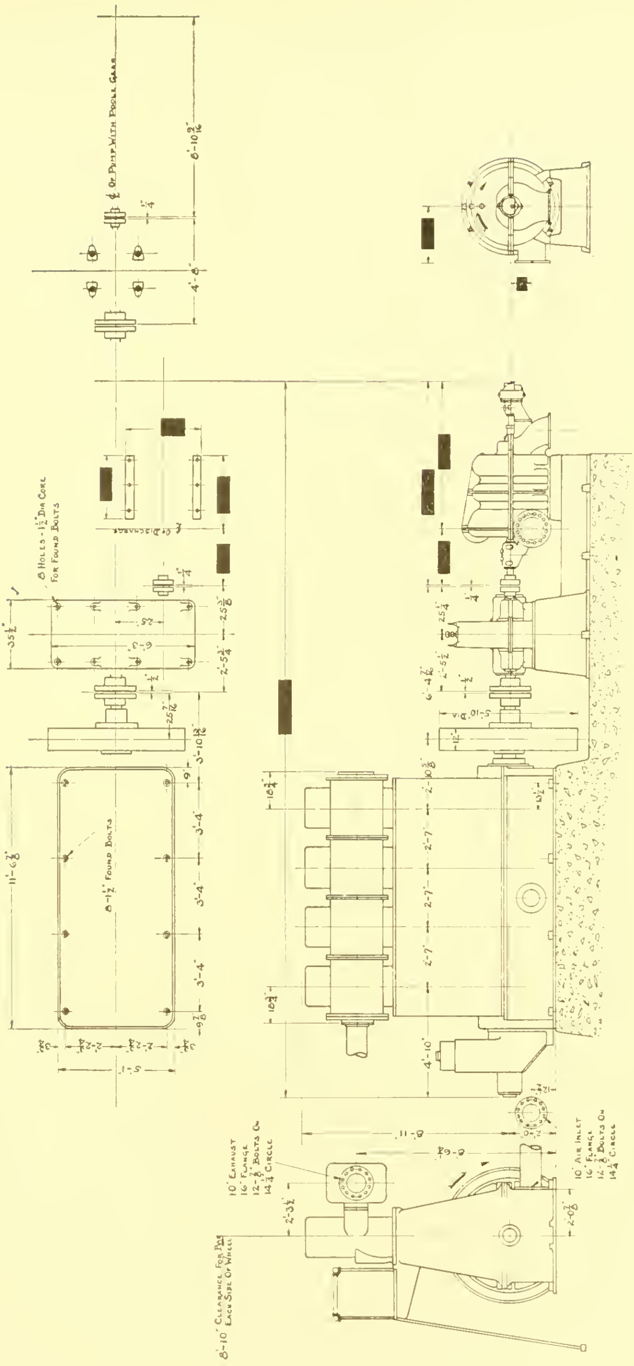

Fig. 23. — Three-Stage Centrifugal Pump, Single Suction, Gear Driven by Four-Cylinder Worthington Diesel Engine.

Water Works Equipment — Steam vs. Oil Engine.

BY RODNEY M. HALL.*

Having been brought up a steam man, I am finding it necessary to more or less change my stripes to become a Diesel engine enthusiast, but I find that it is not at all a hard thing to do.

Twenty years ago, the usual competition in water-works equipment was between direct-acting duplex pumps and crank and flywheel pumps. Both types were usually considered on a comparative investment basis, and it was an open question when bids were received which of the two types would be the most advantageous for any given local conditions. As the years went by, it was a case of survival of the fittest, and the crank and the flywheel steam-driven pumping engine survived. Some direct-acting duplex pumps for water-works service are still built, but only a comparatively small number of such installations are made.

The same reasoning is properly applied to the Diesel engine development at the present time. In comparing Diesel equipment with steam, and in any consideration of new pumping equipment, Diesel oil engines must be included in the studies of various steam possibilities. It is not necessary or desirable to advocate any one type of pump, or drive, or source of power, because all types are now available and all are good. There are some locations where one type will prevail, in others a type of a different kind makes a more suitable installation.

In regard to the first cost, it is fair to presume, in fact it is so, that the Diesel engine-driven pumping engine runs into higher figures than steam-driven units, for the same capacity, when considering only the pumping machinery itself. However, the Diesel engine is a self-contained plant, whereas a complete steam plant must have its stack and boiler house, boilers, stokers, conveyors, heaters and other auxiliaries, in addition to the pumping engine. The gap of cost difference narrows, as a result, to such an extent as to make all classes competitive.

On the smaller units the Diesel pumping-engine first costs more nearly meet the initial costs of other types of pumping machinery than is the case on the larger installations. In fuel economy, the Diesel engine excels all other forms of pumping machinery, and the question, which becomes a local and a special consideration for each case, is how the two types compare in individual instances, considered as an investment. In a great many cases, if the Diesel engine is given the support which it deserves, and it is assumed that it is a safe unit and that it has come to stay, it will be found that on a dollars and cents basis, it fully justifies itself.

The height to which Diesel engine economy carries the "duty" of pumping engines is surprising. A fuel oil consumption of one half a pound per useful water horsepower hour is obtainable as an overall measure of

* Manager, Water Works Department, Worthington Pump and Machinery Corporation.

economy on these pumps and this is equivalent to a horsepower hour for a fuel consumption of approximately 9 250 b.t.u.'s. Translated into "duty," even the small Diesel engines give upwards of 200 000 000 duty per million b.t.u.'s. Every one knows the effort that has been made to reach 200 000 000 duty per 1 000 lb. of steam, and if we assume that the b.t.u. duty is 85 per cent. of the steam duty, which is an approximately correct factor, we have somewhere in the neighborhood of 170 000 000 b.t.u. duty for the *largest* steam reciprocating engine, having 110-in. L.P. steam cylinder, against upwards of 200 000 000 b.t.u. duty on a *small* Diesel engine-driven pumping unit. This point is of the utmost importance — the extraordinary high duty of small-sized Diesel engine units.

The time has surely come for users and engineers selecting pumping equipment to realize that it is to their great advantage to give the Diesel engine the utmost consideration. As we have said before, the Diesel engine is here to stay and the Worthington Company is here to stay. We stand behind the internal combustion product the same as we have always stood behind all our previous output in past years.

Discussion.

The Chairman. In the first place, the Chair wishes to thank Dr. Lucke for his assistance in developing this interesting subject. Now, all of these remarks will be published in the Journal, in which form, of course, they will be much more available for your study and digestion. Still, I think one of the most interesting parts of our meeting can be obtained through a discussion, and now the subject will be thrown open to the membership for a discussion, and Dr. Lucke and these gentlemen who are with him I think will be very glad to answer any questions you may ask, and then I will ask Dr. Lucke to take five minutes to close the discussion.

The subject is now open to you for discussion.

Mr. Vernon F. West.* Mr. Chairman, there is one matter that Dr. Lucke spoke about here on which I should like to have a little more information. In the East here, pumping stations as now constituted have the pumps practically operating under constant speed. That is due largely to the topography of the land, whereby we are able to get sufficient storage to run our pumps at a uniform speed all the time. That is, our run is practically 100 per cent., when it is not we shut down. In the Middle West, where the topography is not the same as with us, their pumps oftentimes are shut down so that they just turn over. That is with steam operation, resulting in inefficient performance.

Now, it is a question to my mind how that will be handled in the Diesel operation. That is, do you get economies in the operation of the

* Treasurer, Rensselaer Water Co., Ft. Rensselaer, N. Y.

Diesel engine at half load, three-quarter load, full load and a little overload, in comparison with the steam engine? I have heard some discussion on that, but I would like to have a little more information as to whether the steam engine is more economical in operating under varying loads than is the Diesel engine. The Diesel engine in a plant can be direct connected to the driven power through reduction or by some other method. But in the operation of a pumping station where the power is dispensed not only through the pumps but through the filtration plant and through other subsidiaries, do you want one Diesel engine, or do you want four or five of them?

The question, to my mind, is whether we had not better use Diesel engines to generate the power electrically and to distribute the power through the stations, than to have four or five Diesel engines each moving one or two pumps. It is a question, to my mind, how the Diesel operates on full load, half load, or other proportion of the load, in comparison with the steam engine.

Dr. Lucke. There are two parts to the answer. One is a matter of engineering facts concerning the engine characteristics, the other is a matter of engineering judgment as to what is the best use to make of those facts.

Now, as to the facts about the engine itself and the characteristics. It may be said that substantially the indicated thermal efficiency is constant at all loads. The efficiency on net output falls off with load reduction because of the substantial constancy of the mechanical losses in the engine. So that the best results in overall efficiency would be obtained by keeping the engine as nearly loaded as possible. That does not mean the same thing with the Diesel engine as with steam, because by using many small Diesel engines which can be started and stopped without warming up, each can take the load just as quick as the valves can be manipulated. It will not hurt the engine a particle to do that and it can be adjusted to its most efficient load without any reduction in efficiency by reason of the multiplicity, as would be the case with steam. Of course, there is a little added expense in using five engines in place of one, not so much on account of the engines as for building and foundations.

Another set of engineering facts is concerned with the speed characteristics of the engine. Operation at sea with the motor-ship engine direct coupled to the propeller is common down to 30 per cent. of normal speed, with such a moment of inertia as is characteristic of the rotating parts of the ordinary marine engine and there is practically no flywheel. So that if one wants to vary the speed of a Diesel engine through any given limit, down even to 15 per cent. of the maximum, it can be done if the requirement is known ahead of time and the necessary flywheel be put in. With the ordinary flywheel, from full to about half speed or one-third speed represents the speed range, depending upon the turning effort of the particular engine on the one hand and the flywheel weight on the other. This can be extended by adding to flywheel masses.

The suggestion was made about generating electric power and distributing it to electric motors. There is one interesting type of case that suggests itself, of which there are some actual examples, and that is general town service where electricity and water are both to be supplied by the town. That is the combined lighting plant and water works. Here it is possible to couple directly generators to each of the engines to operate the lighting service directly and to operate the pumps by motors. In fact, it is possible to distribute the pumps over the transmission line should that be desirable. There will be more of such stations, combined lighting and pumping stations, where the power is developed in the form of electricity directly.

Multiplicity of engines is desirable when there is a periodic fluctuation of load, not only to keep engines operating each at its best load, but for other reasons, bearing on assurance of continuity of service. It must be remembered that the Diesel engine is not only an engine but it is also a furnace, taking fuel into the cylinder and burning it, and therefore certain cleanliness conditions will require attention. What has been accomplished in clean combustion in cylinders is simply wonderful when the conditions are realized, but maintenance of absolute cleanliness of cylinders is impossible over long periods of time. The most minute deposits per minute may make quite a total over a year. Consider the deposits of scale in a boiler with water containing only an infinitesimal amount of solids per gallon. Yet an appreciable amount of scale will accumulate over a period of time. Exactly the same sort of situation exists in the cylinder of the internal-combustion engine. The exhaust may be absolutely colorless and combustion as nearly perfect as anybody can measure; the chemists may be unable to detect any waste products in the exhaust, nothing but carbon-dioxide, nitrogen and water vapor, and yet in time the interior parts will have to be cleaned, the piston rings, the sprayer and the valves. The valves, furthermore, will have to be reground on their seats. It does not take long and it does not have to be done often, but it does have to be done, just as surely as periodic internal cleaning of boilers is necessary.

Therefore, in a Diesel engine plant, provision must be made for periodic inspection, adjustment and cleaning, and if that is done, fine service will surely result. On the ships, this is done; not only the commercial Diesel cargo motor ships, but particularly the ships of the war, — the submarines were all engined with these machines and they gave a wonderful performance, so wonderful that at one time you remember the outcome of the war was very much in doubt. That kind of reliable performance was obtained by a fixed operating schedule, every so many days do this, every so many days do that. A little experience creates such an operating schedule. But to do this and to do that internally, requires that the engine be shut down five minutes or fifty minutes or two hours every once in so often. With multiplicity of units in a station, the ordinary fluctuation of load will give the operator a chance to do the necessary inspecting and

internal cleaning and valve grinding, per schedule. This is the ordinary proper care of an oil engine, which replaces the relining of furnaces, the cleaning of boiler tubes, and all that other work that goes with the steam equipment.

That is the second reason for multiplicity of Diesel units and smaller sizes, and such multiplicity of units does not result in any loss of efficiency with the Diesel engine, which is not true with steam.

MR. FRANK A. MARSTON.* In thinking of this subject in its general details rather than in the analysis of any specific problem, it is of interest to have figures, some round numbers, such as we have in steam practice, for the performance of such an engine.

I would like to ask the question as to what sort of round number would it be safe to have for the fuel consumption of such an engine, or whatever equivalent basis or unit may be in frequent use? Some unit of that kind would be quite helpful, not in analyzing any one specific problem but just in a general consideration of the subject.

Also, in round numbers, an outside figure of what these engines cost per horsepower, approximately, or any other similar unit which is convenient in checking?

DR. LUCKE. The fuel consumption is usually based on a calorific power of oil of 18 000 b.t.u.'s per lb. Most oils are better than that. But there is not very much variation in the calorific power per lb. of oil for quite a wide range in physical properties. It is surprising how constant the calorific power is. On the 18 500 b.t.u.'s per lb. basis, the minimum is about .43, the maximum about .50 lb. per brake h.p. hour. This covers the whole range, from a small two-cycle solid-injection engine at .5 lb. to a large four-cycle air-injection engine at .43 lb., which is not very much.

On the other question, of engine costs, the round numbers that are easy to keep in mind are $65 per h.p. for the smaller two-cycle, up to $75 or $80 per h.p. for the four-cycle engine, depending upon the number of cylinders. Next month, however, that might be different.

MR. SAMUEL A. AGNEW.† One thing that surprises me is the fact that the Doctor says we can reduce the running of these engines to 15 per cent. of their revolutions per minute. I am rather surprised at that. I have had to do with the old type of oil engine, the old H.A. type, and that is a solid-injection type of engine. Now, as you know, the cam operating on the cam shaft operates the oil pump which injects the oil into the machine. If that cam is not operating rapidly enough the oil will sort of slobber into the machine. Now then, unless that oil is sprayed in with force against the other side, you can readily see that you will not get a good combustion, that is, your oil will not vaporize properly. So that I am rather surprised to hear the Doctor say that we could run an engine at, say, 15 per cent. of its normal revolutions. I know I cannot do it with the old type engine.

* Metcalf & Eddy, Boston Mass.
† Superintendent Water Works, Scituate Mass.

Dr. Lucke. That is a perfectly good question and it indicates that "The world do move." Of course it can be done, but it must be known ahead of time what it is necessary to do and then the engine can be made to do it. If one wanted to run at the minimum speed, such a range of speed which is unusual, nobody has ever wanted to go that far, it would require many cylinders to give a reasonably uniform turning effort, as one can readily see. Then by adding a proper flywheel, the 15 per cent. of normal speed comes within reason and such operation will be assured.

As to what would happen with the fuel injection, it must be remembered that the kind of injection described by you would not do and it would not be used. Much has been learned about fuel injection and combustion since your old engine was designed, more than there is time to tell about here, and there are now all kinds of different schemes for injecting the fuel, some of which will do the job. It is a matter of design to meet almost any specifications.

Mr. A. O. Doane.* One of the prime requisites of pumping machinery, especially for municipal works, is reliability. I would put that ahead of economy if I were making a choice. I haven't heard much said on that feature.

There is another feature that is also of a great deal of importance in making a comparison of different types of pumping machinery, in making a choice as to what to install, and that is the relative life of the machinery.

I would like to have some information on those two points.

Dr. Lucke. On the matter of reliability, the motor ship was cited. For a long time no one in stationary practice, certainly no one in this country, was willing to take the oil engine seriously until that most amazing demonstration of the reliability of the motor ship at sea became recognized. One case from my own experience will serve as an illustration. I went down to the water front of New York one day with a party to visit a motor ship that had come in from Manila by way of the Panama Canal. She had been fifty-six days at sea and the engine had never stopped once, full load all the time. That was her regular experience. I have been told of ships, and the insurance and other records will confirm it, that motor ships sail regularly from British channel ports on the other side of the Atlantic to China ports without ever a stop or the loss of a revolution, then unload, reload, and come back. There is real reliability. Now these statements need not be believed on any man's word, they can easily be verified. Look up the records of the motor ships at sea. These records are more or less public property and can be had through Lloyds or the American Bureau of Shipping, and the various marine magazines. In that way any one will be bound to believe that a rightly made Diesel engine is a mighty reliable machine.

We have also some other demonstrations of reliability on land, one group of these happens to be with pumps, pumping oil in pipe lines in

* Division Engineer, Metropolitan District Commission.

the oil-producing sections of the country. I have been told that many pumps with oil-engine drives have operated 100 per cent. non-stop, for 80 per cent. or more of the year. That is pretty good reliability. The necessity for stops is a cleaning necessity more than anything else. They require a few hours every once in a while for cleaning, and a few hours at longer intervals for valve grinding.

With such facts, how can any one say there is no demonstration of reliability of Diesel engines, with so many motor ships at sea with lives depending on them and some millions of dollars of property carried almost around the whole world.

Mr. Agnew. Mr. Chairman, the gentleman asked about the matter of reliability. We started out with one small engine, in a small water company, so that we do not need to go to any one for a reliability test. It was a small works which was hardly able to pay a man to stay at the station all the time. That engine would be started in the morning, the station would be locked up, the engine would be left running to pump all day long. At night the man would go and oil up, and he would lock the station again, go off and leave it at night. In a run of one year I made one test. I checked the engine from February 1, of one year, to February 2, of the next year, and in that time made two stops to take up bearings, not in the engine but in the pump. So that as far as reliability is concerned, I do not see anything that has ever beaten it.

And another consideration is the cheapness. Economy of attendance. To me that is the one great consideration. Instead of having a number of men around to operate boilers and the engine, one man can take care of a number of those plants and do it very easily.

Mr. Frank A. Barbour.* I would like to ask Dr. Lucke whether there is any chance of the situation being altered by the increased use of heavy oils for heating houses, and so forth. Up here in New England this winter we have had rather a severe experience, and we hear that the Geological Survey advises against the use of heavy oils for some purposes. What is the possibility that the situation may change by the using up of the available oil supply?

Dr. Lucke. That is a good question. The oil business today is controlled by the automobile, and everything that is done to produce, refine and distribute petroleum and its products, all revolves about the demand for gasoline for automobiles. Nobody believes that that demand is going to lessen. Everybody believes that that is a stable and more or less regularly-increasing demand, certainly in this country. Now, roughly, not strictly accurate, but good enough for present purposes, for every gallon of gasoline made, there becomes available two gallons of fuel oil that a Diesel engine can burn, and it has got to be disposed of somewhere. The only question is, how? That oil is available. Just in proportion as regularity of use of such oil develops in any one section, so will the oil com-

* Consulting Engineer, Boston, Mass.

panies establish a supply or feeder system. They will provide the supply, they will provide the storage stations just as soon as there is any regular use of fuel oil, and statistics are available of where that has been done. The fear that the household user, or that the steam user, will rob Diesel engine users of that fuel, is unfounded because the economics of the situation is that as the users multiply, the tendency, of course, is for the price to go up in this as in any other commodity. That is natural enough. Then who gets it finally! The one who can afford to pay more and the one who is making the most efficient use of it. And so in that case, as the price of fuel oil goes up, the Diesel engine can afford to take it away from the steam boiler. That is just a natural fundamental and economic principle, especially when it is considered that the steam boiler can be operated on coal, and that coal is available in unlimited amounts.

As to the future supply of petroleum from which to make the gasoline or its fuel oil by-product, it is true that geologists have predicted the end of the world in petroleum, but from personal observation for over twenty-five years they have been predicting the same thing. Most of their predictions have been wrong and they are likely to be so in the future. Apparently the chief value of geologists in the oil business today is to explain why oil was found where it was after it was found and to make predictions about adjacent, not remote or new territory. Ask any oil producer.

The Chairman. If there is no further discussion, I am going to give Dr. Lucke five minutes now in rebuttal.

Dr. Lucke. Gentlemen, there is nothing to rebut and I therefore will not take any more of your time. But in view of the novelty of the subject, and its scope, and the very great importance that there is in it measured by possible consequences in the form of changes in future practice, the suggestion is offered to you that you might think the situation over, discuss the matter with your friends and then when questions arise, as they surely will, send the questions to your Secretary and if your Secretary will communicate the questions to me, I will undertake to have them answered.

APPLICATION OF A BOOSTER PUMP TO A GRAVITY SYSTEM OF WATER SUPPLY.

BY GEORGE F. MERRILL.*

[*February 13, 1923.*]

In order to show conditions connected with the installation of the booster pump, and its effect on the whole system, a brief description of the works is desirable.

The water works at Greenfield were constructed by a fire district in 1872 and operated by it, until about a year ago, when they became the property of the town. Water is supplied to the whole town, with the exception of part of the farming district. The portion supplied includes a population of about 15 000 people. The manufacturing use is of about the average character, with no manufacturer requiring any considerable amount of water for process use. There is a fairly high consumption by railroads and hydraulic elevators. The average daily consumption is 100 gal. per capita. Services are about 15 per cent. metered, covering all except purely domestic use. The supply mains and pipes of the distribution system are of cast iron, with the exception of $\frac{1}{2}$ mi. of wood pipe.

The sources of supply are Glenn Brook, by gravity, with a water-shed of $5\frac{1}{2}$ sq. mi., in the town of Leyden; and Green River, emergency pumping, with a water-shed of about 52 sq. mi., part of which is in Vermont. On Glenn Brook two reservoirs are located, the upper being a storage reservoir with a capacity of 44 000 000 gal.; and the lower, a distributing reservoir with a capacity of 26 000 000 gal. In the wet years and also the normal years, with favorable distribution of rainfall during the summer months, the Glenn Brook water-shed yields sufficient run-off to supply the town. During dry seasons, when Glenn Brook water-shed fails, water is pumped from a well near Green River. This water flows through a natural deposit of sand and gravel to enter the well, and is therefore a filtered supply.

The Green River pumping station is operated by electric power, and contains a 3 000 000 gal. pump, built by the Platt Iron Works Company of Dayton, Ohio. It is 16 x 18 duplex horizontal pump, direct connected to a 200-horse power slip-ring type two-speed motor, through a single reduction of herringbone gears. The two-speed motor allows pump operating rates of 1 500 000 and 3 000 000 gal. per 24 hrs. Water at this station is pumped against an average static head of 245 ft., through a 16-in. force main about 2 600 ft. in length to the point where it connects with the gravity supply mains from the lower reservoir to the town. The dynamic head

* Superintendent Water Works, Greenfield, Mass.

varies from 250 to 285 ft. During the dry years it has been necessary to pump about 100 000 000 gal. per year. The Green River Works for additional supply were built in 1913 and 1914. Prior to 1914, emergency pumping was furnished by a stream plant from the Green River water-shed, taking water directly from the stream, which was discontinued when the additional supply works became available.

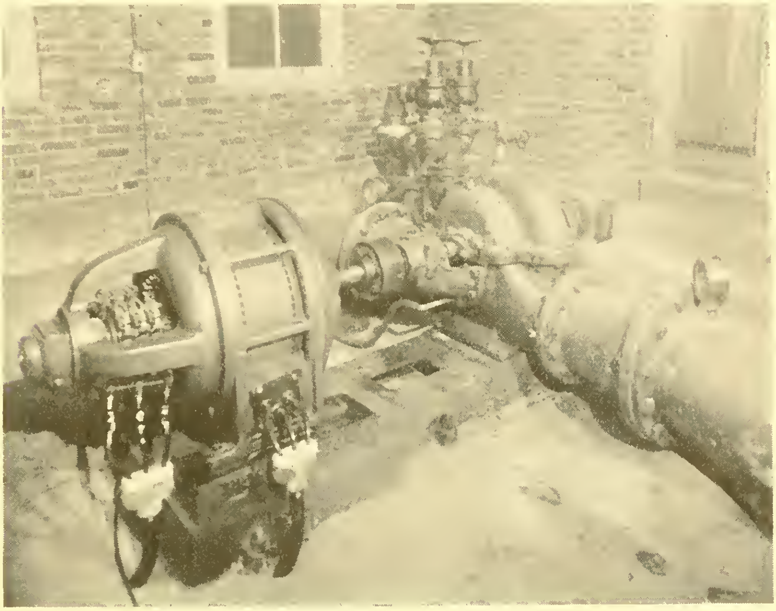

Fig. 1. Motor and Pump, Showing Relief Valves, Greenfield, Mass.

The gravity supply mains from the lower reservoir to the town are parallel. 8-inch and 14-in. cast-iron pipes, with five 8-in. cross connections, allowing the flow to equalize itself in both pipes, which are about 20 000 ft. in length, from the lower reservoir to the northern part of the residential section of the town, where the pipes of the distribution system begin to assist the capacity of the main pipes, and about 26 000 ft. to Main Street, where they connect with the 24-in. main.

The upper reservoir on Glenn Brook is about 50 ft. higher than the lower reservoir, and is connected to the gravity supply mains at a point a short distance below the lower reservoir by a 30-in. main 2 170 ft. in length.

There is also an equalizing reservoir, called Rocky Mountain Reservoir, located on Rocky Mountain on the easterly side of the residential section, about one mile from the principal mercantile section, having capacity of 2 500 000 gal., and at an elevation of 200 ft. above the principal mercantile section. When filled, its water surface is $32\frac{1}{2}$ ft. lower than the surface of the lower reservoir. This reservoir is connected with the distribution

system by a 24-in. main about 5 000 ft. in length, which extends through the business section and connects with the mains of intersecting streets.

During average conditions of supply, and all times when the consumption does not exceed 1 500 000 gal., for 24 hrs., water is supplied from the lower reservoir, and the supply mains will deliver this amount by gravity flow and keep the Rocky Mountain Reservoir full. As this reservoir is of great importance to furnish a ready volume of water for fire service at hydrant pressure, it is very essential that it be maintained practically full at all times. At times, water consumption is at considerably higher rate than the capacity of the supply mains. If this condition does not continue over a considerable number of days, the Rocky Mountain reservoir will furnish supply enough, as it has the night flow to fill it when water consumption for legitimate use is at a low rate.

In case the higher rate of consumption is continued for several days, its effect will be lowering of the water level in Rocky Mountain Reservoir, — unless a higher rate of flow in the supply mains can be furnished. Previous to the installation of the booster pump, the higher rate was obtained either by operating the Green River pumping station or by using the upper reservoir with its additional head and feeding through a throttled valve at the rate desired. In the winter season either method is expensive and wasteful, as in either case considerable quantities of water must be wasted in order to maintain circulation enough to prevent freezing in the exposed lines of pipe which pass through the gorge below the lower reservoir.

The booster pump is located at a point on the supply mains about 5 000 ft. towards the town from the lower reservoir, and about 1 000 ft. towards the town from the point where the force main from the Green River Pumping Station connects with the supply mains. The station is a brick building 18 x 22 ft. in which the pump is located. The pump is connected on a by-pass from the 14-in. main, and a 16-in. check valve is located in the main line between the branches, a larger check valve than the main-pipe size was used to eliminate as much as possible of the loss of head which this type of valve causes.

The pump is an 8-in. Worthington Centrifugal, with bronze impeller adapted to the hydraulic conditions, direct connected to 50 h. p. 550 volt-1 735 r.p.m. approximate full-load speed, from M, slip-ring-type, constant-speed motor— with drum controller. The control panel contains an ampere meter, one indicating watt-hour meter, a recording watt-hour meter, and starting switch with automatic oil circuit breaker with double-series, inverse-time-limit overload trip. The electrical equipment was furnished by the General Electric Company. On the discharge side of the pump are connected two 4-in. Crosby water-relief valves as a protection from surges of pressure.

The water pressure on the pump is 86 lb. When operating, the water pressure drops to 82 lb., on the suction side, and on the discharge side the pressure is 108, indicating a dynamic head of about sixty feet. The in-

creased pressure of 22 lb., on the discharge side is practically all consumed in friction loss in the supply mains due to the higher velocity. The discharge rate is 2 600 000 gal. per 24 hrs., increasing the capacity of the supply mains above the rate of gravity flow from the lower reservoir, by 73 per cent. The increased capacity was possible in our case because of low velocity obtaining under gravity flow from the lower reservoir, the calculated

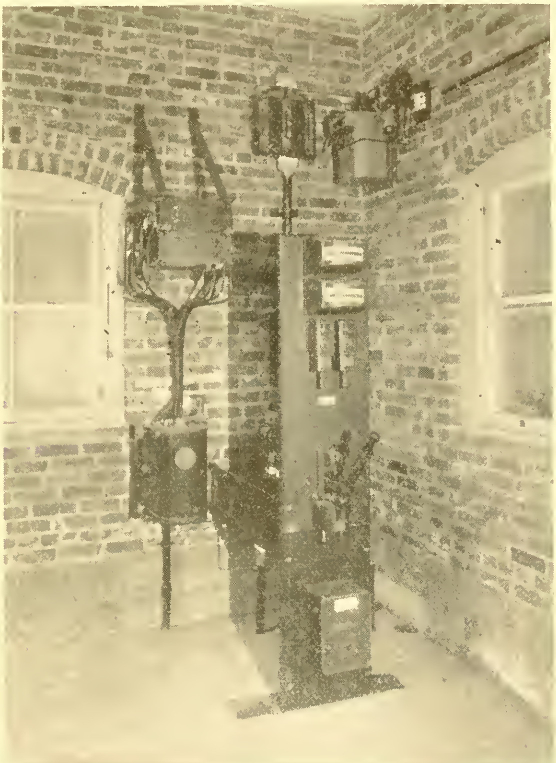

Fig. 2. Control Panel, Booster Pump, Greenfield, Mass.

Motor Control Panel, with Ampere Meter, Indicating Watt Hour Meter, Recording Watt Hour Meter and Starting Switch, with Oil Circuit Breaker, and Double Series Inverse Time Limit Overload Trip.

velocity being 1.67 ft., per sec. With the booster pump operating, the velocity increases to 2.78 ft. per sec.

Operating tests on the pump have shown the plant efficiency to be 75.2 per cent., which may be considered high for a plant of this size and type of pump.

The cost of installation was about $6 300 which included the building and all equipment and also covered the cost of about 3 300 ft. of three-phase, electric-power line.

The cost of pumping with electric power, at an average price of $2\frac{1}{2}$c. per k.w. hr. will be about $8.20 per mil. gal., and the cost per mil. gal., raised one foot dynamic will be about thirteen cents.

The value to our system lies in the fact that an expenditure of about $200 000 for larger supply mains may be delayed until more favorable construction costs can be obtained.

In connection with this work, Allen Hazen, Consulting Engineer of New York, was consulted, and the work of installation was done by the department.

The cost of operation will be low, as present conditions indicate that an average run of a few hours a day will provide the necessary added capacity.

The successful application of a booster pump in other systems to increase main pipe capacities will depend wholly on the local conditions; and the greatest gains can be obtained in cases where the velocity of flow in the main pipes is low, thus permitting increased velocities and still keeping within the limit of economy in operating.

Present construction and operating costs make it imperative that water-works engineers and managers obtain as high efficiency as possible in every way. If there are cases where we can make our mains work more efficiently, substantial savings can be made; as they represent a considerable portion of the cost of every water system, and, as has been shown, it may sometimes pay to pump water down-hill.

Discussion.

President Sanders. I would like to ask, Mr. Merrill, if you have any means of measuring the water that is pumped—any Venturi meter on the discharge side of this pump?

Mr. Merrill. The discharge is metered by Venturi meter at a point about a mile from the station, and in considering the efficiency we have to make an allowance for what leakage occurs between the station and the meter. There may be some.

President Sanders. Do I understand you to say that you pump without an attendant at the pump.

Mr. Merrill. Well, we have not yet. It has only been operated a short period. It is a question of starting and stopping. Running for a stated period which can be determined beforehand. Possibly two hours today and three tomorrow is all that is required. That can be determined beforehand.

President Sanders. Do you always find that the check valve works? That is, when you start your booster pump does the operation of the pump close your check every time?

Mr. Merrill. We have found it did so far. I would say that those who are contemplating an installation of this kind had better look up the loss of head that you get from the check valve. We made it a size larger than the main-pipe size to avoid that as much as possible, but it has quite an advantage in the fact that when you shut your pump down it allows the flow to go along the main line, preventing a surge in pressure which might be quite destructive in a long line.

Mr. E. P. Howard.* I do not know as I ought to take the time to say anything, as the hour is getting late. But I might just say that you probably noticed from Mr. Merrill's remarks the high efficiency of the pump, which figured out about 84 per cent., and which coincides very closely with what our President, Mr. Sanders, obtained with a similar installation in his plant. Now, that simply shows what can be done with a centrifugal pump of the right kind under the most favorable conditions when it is put in. A great deal of credit for this is due to the way it is installed. A large amount of credit is also due to how carefully the heads were figured out, so as to bring everything to practically a 100 per cent. point. The heads actually, I believe, in service, worked out within 5 ft. of what they were calculated in both of these plants.

Now I hope you won't take these two plants and the high efficiency that is obtained as something which would indicate that centrifugal pumps can be used in all places. In some places — in fact, places like this, where everything is favorable — they are the best thing in the world to use. There are other places, however, where they are the poorest thing in the world to use. Every job must be gone over, and every kind of a pump investigated to determine which is best for any particular case. In cases like this, as has been proved, it was the ideal thing.

* Of Worthington Pump and Machinery Corporation.

TOPICAL DISCUSSION.

Water Rates.

[*February 13, 1923*]

Mr. A. C. Dickerman* (*by letter February 8, 1923*). In response to the suggestion on the recent notification of the February 13th meeting, I would like to hear what some of the other members have to say as to the desirability and possibility of making rates that will insure the Water Company getting a satisfactory return for water sold to takers owning more than one house upon a lot or parcel, and who are supplied with water taken through a single meter located on that property.

It does not seem just to the Water Company that when a real estate owner has built several houses on a lot he should be able to buy water at wholesale from the Water Company and perhaps retail it to the tenants in the several houses, and it might also be considered a discriminatory practice.

It would seem wise to require a separate service and meter for each house, even when two or more houses are on the same parcel of land owned by a single party, in all cases where said services may be installed without unusual cost, and in other cases, permit a single service and meter but require a payment for each family or house supplied in addition to the actual price of the water passed through the meter.

I would be glad to hear what some of the other members have to say on this matter with particular reference to a privately-owned company.

I have been making some investigations of our accounts, and I find in my particular Company that it has been the practice in times past to connect up property, supplying it with water, so that later on, perhaps, when new houses were built on this parcel they would take the water from the original house and through the original meter. I think that this is wrong as it is not fair to the company.

There have been a number of such houses supplied, and I was startled when I found out how far it had gone. I have no doubt this condition is not an unusual one in other communities, because when towns are being developed of course the development is scattered. There is no rule requiring houses to be built next to each other on any particular street; consequently, there are a great many cases where some one wants water, and it is difficult, perhaps even prohibitive, as far as expense is concerned, to supply them from new mains. As a result the water companies have found temporary ways of supplying them with water, and I believe that these conditions lead to a very distinct loss of revenue.

Perhaps some of the members here have been able to work out some way of handling this situation satisfactorily so that proper terms will be made giving the Water Company a reasonable revenue and at the same

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* Superintendent East Providence Water Co.

time not being too harsh on people who would otherwise have difficulty in getting water.

Mr. H. J. Goodale.* In Attleboro when the water system was first installed, and for a number of years after, each property-owner was allowed to connect as many houses to one service as he wished. This rule still applied after meters were introduced so that the owner of the property had the privilege of purchasing water at wholesale. After a period of time the Water Commissioners made a rule that each house must have a separate service but nothing was done to correct the existing conditions.

When the town became a city and new regulations were made it was decided that in all fairness, these conditions should be corrected so that a new rule was passed which was this: Where more than one building is served by one meter, water used in such buildings shall be charged for in the same manner and at the rates as though a separate meter was set in each building. Excess water shall be apportioned equally among the buildings so served.

Should more than one meter be set in any building, the established water rates shall be charged for each meter set, and in no case shall the water measured by one meter pass through another meter.

The term " building " shall include garage, barn or other out-buildings appurtenant to the main building.

Mr. Reeves J. Newsom.† Our experience in Lynn has been very similar to that in Attleboro. In times past more than one house was occasionally served by a single service, through one meter in the front house, and our practice has been in recent years not to allow any installations of that kind, but on those installations that were already in operation a minimum charge was attached to each house and then the excess was billed. Ordinarily the bill went to one owner anyway, and he merely paid two minimum charges, or three, as the case might be, plus the excess at the base rate, so that the amount of his bill was exactly the same as though it were for three independent houses. The only advantage that he could derive in that case would be that he would pay for a single meter installation rather than for three, and that is the only argument we now have to meet where the physical conditions are such that this sort of thing could take place.

Mr. Henry V. Macksey.‡ Another phase of that question has not as yet been touched upon. We have a landlord who owns town house property built in blocks of three or four, and one of his ideas on economy is that he will serve his tenants only with the minimum amount of water for which he must pay, and he will leave them to pay the rest.

He notified us that we might collect from them, which we did not consider practicable, and we refused to do it. He then requested that we give him a separate meter for every tenement, which request we refused. Then, as he would not pay the rates demanded we shut the water off. The Board

* Town Manager, Middleborough, Mass.
† Commissioner of Water Supply, Lynn, Mass.
‡ Superintendent of Public Works, Framingham, Mass.

of Health intervened and demanded that the water be turned on. Then, we called upon the Board of Health — it was a health matter — to pay the water rates from the funds at their disposal before we turned the water on. That shut off the Board of Health for awhile. If it was a matter of health, why, the Health Department should take care of it; if it was a matter of selling water, we would not sell the water unless assured of payment. The landlord then came around with his tenant and the tenant demanded water, which we refused and we referred the matter to the Town Council, who said, "Why, you are supposed to supply water to all the citizens of Framingham whether they do or do not own property." We explained our difficulty in collecting bills. He said, "you may make any *reasonable* regulation you please, but you must supply the water." It appeared to us that the reasonable regulation was, that instead of one service supplying the block with one meter, there would have to be a separate service go into each tenement, each tenant having his own meter. We accepted tenants applications, and put in the meters. All went well until one tenant left. He came in and reported that he wanted no more water. We settled with him. Then he went to settle with his landlord, and he wanted to deduct what he had paid for his share of the service, his plumber's bill and his minimum water charge. The landlord, being of a trusting, unsuspicious nature, came around to us to find out how much money the tenant had spent. We would not tell him. We told him we were not doing business with him at all; we didn't know him in the matter. He sent his counsel in, and the counsel said, "Why, the statute says that the landlord, the owner of the property, is responsible for all the water served to his tenants." We said, "Why, we know it does, because our counsel told us so; but our counsel also told us that we have to supply the tenant if he demands it." We did not go to counsel the third time, because we did not think it was necessary to have him tell us that if we make a deal with John Smith that we cannot tell Tom Jones he will have to pay the bill later on. We said, "You didn't have any part in the contract; the contract you had with us to supply water to the premises was ended when we began to do business with the tenant. You said you would not pay any part of it." Well, the counsel for the landlord, after talking for a half hour, went away. He did not get the facts or the figures. But we have a new town counsel now, and we are going to ask him if a regulation to the effect that we will sell water to the owners of real estate only and not to the tenants is a reasonable regulation.

President Sanders. I think your regulation would be a very reasonable one, Mr. Macksey. That is the way we have the good fortune to do. We collect from the owner only; we don't know who the tenant is. It is a good deal easier to find the owner than it is the tenant.

Mr. Macksey. I will tell you about another thing along the same line. We are just about to establish a sewer-rental system and one of our big business men is on the committee to arrange therefor. He has been a

Water Commissioner for a number of years. When he was placed on the committee for establishing sewer rentals, he wanted to get out of it easy, so he said, "We will make the rental a surcharge on water." So now the sewer rental is a surcharge of 35 per cent. on water. He said further, "You can add it to the water bills." But the Act under which the sewer rental was established says it shall be collected the same as taxes. Now, the taxes are collected by a tax collector, upon a warrant which is served by an officer, or whoever it may be that serves them, and he collects ordinarily. He serves a notice and if payment is not made by a certain date interest goes on at 6 per cent. It costs a quarter for the notice, or something like that. He then serves another notice, which costs another quarter and then sends a man after you and charges $2.50. After a while perhaps he threatens you with jail. He usually advertises the property for sale and gets or sells the tax title. That is different from our method of collecting for water. If a man gets a water bill and it happens to be $10 for water and $3.50 for sewer, and says, "Here is your $10 for the water," we must serve him water. But our counsel seems to think that it is proper to render the both items as one bill, and if any part is unpaid to shut off the water.

Mr. George W. Batchelder.* We have very few places that are supplied by one meter.

I just want to say one thing touching on what Mr. Macksey has said. We do not have anything to do with selecting the Town Counsel — or City Solicitor, as we call him in Worcester — but we try to have a lot to do in training him in water-works law.

Mr. Stephen H. Taylor.† In New Bedford we make the owner of the building responsible for the water rates. If he wants to sub-divide his bill among his tenants he buys his own private meters and puts them in the branches that go to his various tenants. We bill according to the main meter where the water enters the property. We have been able to get away with that very comfortably so far.

On the matter of connecting, we do sometimes connect the services through to a house in the rear, and I think perhaps the idea of getting the minimum charge for that connection is good, although we have not done it in New Bedford. It occurs to me, however, would that be a proper charge if a man built a garage, for instance, in the rear of his house and wanted to run the water pipe back there for convenience, to a part of the same property? We do not have very many cases where we connect one to another except where a house in the rear faces a street on which there is no water. Then naturally it is better to do that than it is to put in a new main for him.

There is another side to that question. In New Bedford, for instance, we get a tapping fee of $2 for service that costs from $25 to $35 to put in. Now, if we can get two houses on that one service we are about $22 to $32 to the good on the original outlay. If the owner pays the whole bill, that would be another matter. In our particular case the city bears the larger part of the cost of the service.

* Water Commissioner, Worcester, Mass.
† Superintendent Water Works, New Bedford, Mass.

Mr. Dickerman. I am reminded of a couple of things that have come to my attention in our company. In one case, some ten years ago, a thing of this sort was done. A man who had a house asked for water, and he immediately built a second house back of him on a street in which there is no water. Then he built two more houses upon this second street. The necessary papers were drawn up, giving the Water Company an easement to cross this second lot into the second street, to reach the last house built. The second house was later sold and then sold again, and in the last sale nothing was said in the deed referring to this original easement. Then the last owner got the idea that he was damaged, and sued the man who sold the property to him, for $2,000 and tried to collect. Of course the parties came to me and wanted some help. It meant in our case running about 500 ft. of pipe at our expense to overcome the cause of the suit, and I believe we will actually do it, because we want to eliminate these unsatisfactory and illogical arrangements of pipes. But this puts a burden on the Water Company, as there will not be enough customers, probably, to even pay the interest on the money involved.

There is a second case somewhat like this although the company will not be put to much expense by it. A service pipe was run across a lot to reach a house in the rear, the property was divided and sold to two different people, but nothing was said in the deed about the water pipes. This developed into a neighborly row and has been taken to the courts.

Mr. Henry T. Gidley. We have a situation in Fairhaven that is somewhat similar to the last speaker's. A man built a store on the main-pipe line with a tenement above. He lived above his store. After a little while he built a cottage back of the store. There was no water pipe on the other street, and he wanted to connect to the same meter the pipe that ran through the cellar of the store into the cottage in the rear. We allowed him to do that, and all went well for a while, until finally he sold his cottage to one party, and the store to another. Then we collected a minimum amount from the party in the rear. But the man who bought the store had a lot of surface water run into the cellar, and he had to pay for an enormous quantity of water which he used in a water motor to pump out his cellar every time it rained, so that his bill ran up excessively large, and he refused to pay it. The people in back had already paid their bill, and when we shut him off for a part of the day to see if we could not force him to pay, it was hardly fair on the people in back. He scraped up $5 and said he would pay the rest. There was no way we could collect it. But finally the original owner of the store foreclosed the mortgage on the property, and when the final papers were passed he made the man deposit enough money to cover the water bill, so that we got out of it that way. The first thing we did was to lay a pipe down that street and connect up with the other houses. There are very few places that we have had that way, and most of them have turned out disastrously. Where a man owns two houses, and one is back of the other, we let them run through one meter, but we collect the minimum charge for both houses.

* Superintendent Water Works, Fairhaven, Mass.

REPORT OF THE JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR WATER METERS.

To the American and New England
Water Works Associations:

Your Committees on Standard Specifications for Water Meters, acting as a Joint Committee, now submit a final report accompanied by a draft of Standard Specifications for Cold Water Meters of the current, compound and fire-service types. There has not appeared to be any reason for modifying the specifications for meters of the disc type which were adopted by the Associations in 1921.

The specifications for disc meters were printed with the Committee's report which was submitted to the American Water Works Association on June 9, 1921, and to the New England Water Works Association on September 14, 1921, and may be found in the American Association's Journal for that year, page 273, and the New England Association's Journal, page 187. That report was submitted as a final report upon the assumption that a standard specification for disc meters was all that was really needed, since few, if any, meters of other types are bought on the basis of competitive bids. Both Associations, however, indicated their desire that the Committee continue its work and prepare specifications for the other principal types of meters, as well as giving consideration to the experience with the specifications for disc meters with a view to revising them, should any change prove desirable.

The experience of two years with the standard specifications for disc meters has not indicated the desirability of any change.

Your Committee decided to prepare similar specifications for current, compound and fire-service types of cold-water meters. It did not seem necessary or desirable to attempt standard specifications for hot-water meters.

The specifications for disc meters have served as a general basis for those of other types. Through the coöperation of the Standardization Committee of Meter Manufacturers, Mr. R. K.

Blanchard, chairman, a preliminary draft of standard specifications for current and compound meters was prepared. This was circulated to the membership of the Joint Committee and later was discussed in detail at a meeting of the Committee, when certain modifications were decided upon, and it was also agreed to prepare specifications for fire-service meters. The modifications proposed were worked out and incorporated in the draft of specifications on behalf of the Joint Committee by Mr. Edward Nuebling of the Department of Water Supply, New York City, to whom the Committee is greatly indebted for this and for other assistance in its work. The revised draft was further considered by the Committee and by representatives of the meter manufacturers before its adoption in the form now submitted to the Associations.

In connection with the specifications your Committee decided to present certain prefatory notes, including information submitted as addenda to the specifications for disc meters, and other explanatory matter, which it was felt ought to be available in connection with the specifications, although not properly forming a part of them.

It is assumed that after the standard specifications have been adopted by the Associations they will be reprinted, together with the specifications for disc meters, in a single pamphlet for general use.

One point which the Committee does not consider practicable to standardize through the specifications at the present time, but which it is hoped the manufacturers may find it possible to standardize in the not distant future, is the arrangement of dials on meter registers. It is very unfortunate that the sequence of dials should vary with certain makes of meters, but it has not seemed wise to your Committee to attempt to fix a standard in this respect for immediate adoption.

Respectfully submitted,
For the Joint Committee.

CHARLES W. SHERMAN, *Chairman.*

William W. Brush, *Chairman.*
Charles W. Sherman, Henry V. Macksey,
A. W. F. Brown, James A. McMurry,
R. J. Thomas, John H. Walsh,
N. E. W. W. Ass'n Committee.

Caleb M. Saville, *Chairman.*
Dow R. Gwinn,
R. J. Thomas,
Seth M. Van Loan.
Am. W. W. Ass'n Committee.

FEBRUARY 24, 1923.

GENERAL INFORMATION.

(These notes are not a part of the specifications. They are inserted for the purpose of providing proper definitions and general information which is frequently necessary in calling for bids, testing meters, or otherwise passing upon their suitability.)

TYPES OF METERS.

Service meters in use for measuring water delivered to domestic and commercial consumers are divided into four general classes, as follows: displacement, current, compound and fire service.

Displacement Meters. There are a number of different types of displacement meters on the market which are known by the motion of the piston, as, reciprocating, rotary, oscillating and nutating disc meters. These meters are positive in action and displace or carry over a fixed quantity for each stroke or revolution of the piston or disc.

Displacement meters are manufactured in sizes from $\frac{5}{8}$ in. to 6 in. They are suggested for universal use on supply lines to dwellings and for use in other locations where accuracy of measurement is a primary consideration.

Current Meters. There are several different types of current meters on the market which differ from each other mainly in the shape of the water wheel or propeller. These meters are not positive in action, but record the flow by the number of revolutions of their water wheel or propeller, which is set in motion by the force of the flowing water coming in contact with the wheel or propeller blades.

Current meters are manufactured in sizes from $1\frac{1}{2}$ in. to 20 in.* These are cheaper in first cost and maintenance and offer less obstruction to the flow of water through them and therefore give a greater discharge with the same loss of head than displacement meters. They are not sensitive to small flows, and not as accurate and reliable as meters of the displacement class on the larger flows.

Meters of the current type are appropriate where a free discharge and heavy service is demanded, as for example: railroad standpipes, elevators, water carts and water motors.

Compound Meters. Compound meters consist of the combination of a main-line meter of the current or displacement type for measuring large flows and a small by-pass meter of the displacement type for

* Sizes larger than 12 in. are so rare that the Committee has not attempted to give the detailed figures for meters above that size.

measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter.

The automatic valve, which is of the differential type, remains closed until the flow is large enough to create a fixed difference in pressure between the inlet and outlet side of the valve. The by-pass meter measures the small flows that otherwise would not be measured or would be measured in part only by the main-line meter. Compound meters are manufactured in sizes from $1\frac{1}{2}$ in. to 12 in. They are suggested for use in cases where flows through the meter cannot be confined to rates within the accuracy limits of a single meter.

Fire-Service Meters. Fire-service meters are compound meters consisting of a main-line meter of the proportional type for measuring large flows and a small by-pass meter of the displacement type for measuring small flows together with an automatic valve mechanism for diverting the small flows through the by-pass meter. The combination is designed to afford a clear passage through the meter when the valve is raised from its seat.

Fire-service meters are manufactured in sizes from 3 in. to 12 in. They are the type required by the Fire Underwriters on sprinkler or fire hydrant connections if minimum fire insurance rates are to be secured. The measurement of flow recorded on the main-line meter is liable to be inaccurate unless careful attention is given to keeping all parts of the meter in good working condition. When the flow through the meter is such as to bring the main-line meter into use, only a relatively small portion of the total flow actually passes through the main-line meter. This increases the liability of serious error in the registration of the water passing through the meter.

Maximum and Minimum Lengths of Meters.

A standard over-all length has been fixed for each size of disc meter. Due to the large variation in the over-all length of each size of current and compound meters that exists among the various makes of meters, it has been found impracticable to fix a standard over-all length for these types. A filler piece can be inserted to increase the length of the shorter meters. Manufacturers are prepared to supply these filler pieces when required.

The following minimum and maximum over-all length, in inches, of the various sizes and types of meters is given to aid those who may desire to provide space for the maximum length of any meter:

Size, Inches.	Disc Standard Length.	Current Minimum Length.	Current Maximum Length.	Compound Minimum Length.	Compound Maximum Length.
$\frac{5}{8}$	$7\frac{1}{2}$	—	—	—	—
$\frac{3}{4}$	9	—	—	—	—
1	$10\frac{3}{4}$	—	—	—	—
$1\frac{1}{2}$	$12\frac{5}{8}$	13	$15\frac{1}{4}$	$18\frac{5}{16}$	$18\frac{5}{16}$
2	$15\frac{1}{4}$	$15\frac{1}{4}$	19	$15\frac{1}{4}$	$28\frac{7}{8}$
3	24	20	24	24	$37\frac{1}{8}$
4	29	22	$29\frac{1}{4}$	29	$39\frac{1}{4}$
6	$36\frac{1}{2}$	24	$36\frac{3}{4}$	36	$50\frac{3}{4}$
8	—	$26\frac{3}{4}$	$48\frac{3}{4}$	42	$61\frac{3}{4}$
10	—	30	60	$63\frac{1}{2}$	$72\frac{3}{4}$
12	—	36	70	$64\frac{1}{2}$	77

Tests of Meters Recommended.

The tests to be made on the meter are divided into two classes:

1. Capacity test.
2. Registration test.

Capacity tests are those which test the design of the meter rather than the workmanship thereof. When a meter of a given make has once been tested for capacity it should not be necessary to again test this type of meter unless a change has been made in its design.

The registration tests should be made on each meter, as the results are affected by workmanship and assembly of individual meters. There is no certainty that, because one meter of a given make comes within certain limits of accuracy, another meter of the same make turned out by the factory on the same day will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and purchaser in making registration tests.

The registration tests recommended are as follows:

All meters should be tested for accuracy of registration within and as near as practicable to the low and high rates given under "Normal Test Flow Limits." Occasionally additional tests should be made at one or more intermediate points.

A test at the "Minimum Test Flow" should be made on as many as possible and not less than 5 per cent. of the meters. If the results obtained from testing 5 per cent. of the meters show that any meter does not comply with the low-flow requirement, additional

meters should be tested to the extent deemed necessary to make certain that the other meters do comply therewith.

The accuracy of compound and fire-service meters within the "change over" range should be determined by making a sufficient number of tests at different rates of flow between the high and low rates given under "Normal Test Flow Limits" to enable the construction of a representative accuracy curve. The rates of flow at the beginning and end of the "change over" and the maximum error in registration can readily be determined from this curve.

A test for accuracy at the "change over" should not be necessary on all meters since this is a test of design rather than workmanship.

Attempt should not be made to test large-size meters if the higher rates of flow necessary to make a proper test cannot be obtained with the apparatus available.

The pressure test should be made on each size of meter furnished of a particular type. This pressure is to be 150 lb. per sq. in. and the pressure may be furnished through the use if a hand pump or such other method as may be available. Before the meter has been tested by static pressure and also after it has been so tested, it should be tested for accuracy to see whether the meter has been so distorted as to affect registration. It is considered unnecessary to make a pressure test of each size of meter of a given type more than once if satisfactory results are obtained.

If it be possible to give a working-pressure test under 150 lb. per sq. in., then such a test should be applied rather than a static-pressure test.

Where the purchaser does not have the necessary equipment to test the meters, there should be furnished by the manufacturer a certificate that each meter has been tested for accuracy of registration and complies with the standard specifications in this respect, and that the size and type of meter furnished has complied with the capacity requirements. When compound or fire-service meters are purchased, the certificate furnished by the manufacturer should include a statement to the effect that the size and type of meter furnished has complied with the standard specifications in respect to registration of flows within the "change over" from the by-pass meter to the main-line meter.

Equipment Necessary to Test Meters for Compliance with Registration and Capacity Requirements as Set Forth in the Standard Specifications for Water Meters.

The standard specifications require that meters shall accurately record the flow within certain limits and shall pass a given quantity of water with a maximum loss of pressure. Suitable equipment to make accurate tests must be available before the purchaser should make complaint of meters not complying with the specifications.

The minimum test equipment required for registration and capacity is as follows:

1. A quick-acting valve on the supply pipe through the use of which the flow can be started and stopped without appreciable loss of time.

2. A valve on the outlet side of the meter which can be used to establish the rate of flow desired.

3. Pressure gages connected on both the inlet and outlet of the meter to show whether any material change in pressure occurs during the period of test which would affect the rate of flow. The outlet pipe is to have sufficient head on it so that the meter will always have pressure on its outlet end and preferably not less than 5 lb. per sq. in.

4. A measuring device which may be either of the volumetric or weighing type. Whichever is used, the accuracy of determination of the volume or weight of water discharged into the measuring device must be such as to bring the limit of error within one-tenth of 1 per cent. The volume of water passed must be sufficient to cause at least one revolution of the pointer on the initial dial except for test at "minimum test flow" rate. For the latter test, the amount passed shall not be less than one cubic foot.

It is desirable to have available for testing meters a test table and appurtenances which are manufactured by several concerns. Such an outfit would include the equipment enumerated in the preceding four paragraphs.

For the capacity tests, it is necessary to add to the above equipment, two piezometer rings which must be of exactly the same diameter. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring and not less than four holes shall be provided, drilled in pairs and on diameters at

right angles to one another. The inlet piezometer ring shall be set close to the meter and shall be at a distance of not less than eight diameters from the nearest upstream stop-cock or fitting in the supply pipe. The outlet piezometer ring shall be placed at a distance of not less than eight nor more than ten diameters from the outlet of the meter. The diameter of the piezometer rings and inlet and outlet pipes shall be the same as the size of the meter to be tested. The piezometer rings are to be connected by either rubber or metal tubing to a mercury U-tube. To this U-tube is to be attached an accurate adjustable scale for measuring the differences between the inlet and outlet pressures. Provision is to be made for the complete removal of air from the tubing connected with the U-tube, and the U-tube and the tubing connected therewith are to be so placed that the air will rise to the outlets. Where relatively high flows are to be recorded, it is necessary to read both sides of the mercury column to compensate, as far as practicable, for irregularities in the diameter of the glass U-tube, and such readings are to be made as nearly simultaneously as possible to avoid errors due to fluctuations.

Information to be Furnished to Meter Manufacturers When Requested to Submit Bids on Meters.

1. Meters shall conform to the Standard Specifications for Cold Water Meters, ... Type, adopted by the American and New England Water Works Associations.

2. The manufacturer shall state in his bid the type of meter he proposes to furnish, as listed in his catalogue. The actual capacity of each size of meter called for is to be given graphically from 0 lb. up to 25 lb. loss of pressure. If this capacity be stated in the manufacturer's catalogue reference may be made thereto.

3. No bid will be considered on meters of a design which has not been listed for at least one year in the catalogue regularly issued by the manufacturer.

4. The method of testing meters shall conform to that recommended by the Committee on Standard Specifications for Water Meters.

5. (*a*)* The meters are to be accepted on a certificate furnished by the manufacturers that the meters have met the requirements of the Standard Specifications for Water Meters, as adopted by the American and New England Water Works Associations.

(*b*)* The meters will be tested by the purchaser to determine whether they do or do not comply with the Standard Specifications for Water Meters adopted by the American and New England Water Works Associations.

6. Registers shall be $\left\{\begin{matrix}\text{round}\\ \text{straight}\end{matrix}\right\}$ reading, and shall record in $\left\{\begin{matrix}\text{cubic feet}\\ \text{gallons}\end{matrix}\right\}$.

Care of Meters.

In all types of displacement and current meters the motions of the piston are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, such as cubic feet or gallons. The gearing serves to translate the motions of the piston into the units of measure indicated by the register.

The register is at all times a measure of the number of revolutions of the piston. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and, after proper calibration, will continue to register correctly only so long as the piston continues to make the proper number of revolutions for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the piston is compelled to make less than the proper number of revolutions per unit of quantity passed through it, the meter will under-register. If the piston is compelled to make more than the proper number of revolutions, the meter will over-register. The proper number of revolutions is the number made at the time the meter is calibrated. The actual number is not important and is ordinarily not determined. There are, under ordinary working conditions, a number of factors that may cause under- or over-registration after comparatively short periods of time. The more important of these factors, which should be guarded against to secure proper registration, are described below:

Excessive Wear. Excessive wear of the moving parts of the meter may be caused by over-speeding, or, in general, by the selection

*Sentence (*a*) is to be used where the purchaser does not have suitable equipment to test the meters. If he has such equipment then sentence (*b*) is to be used.

of meters too small for the work required. The effect of excessive wear of the piston or piston chamber is to cause slippage and under-registration. Excessive wear of the intermediate gear train may cause binding of the gears, breakage of gear teeth or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should not be run at destructive speeds.

The rates of flow corresponding to 25-lb. pressure loss, given in the standard specifications for cold-water meters, represent the maximum rates at which water should be passed through meters for short periods of time. They represent peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the disc or displacement type should not be operated under flows greater than one-fifth the capacity of the meter. Meters of the current type can be operated at higher rates than displacement meters, but for continuous 24-hour service the rate should not exceed one-third the capacity of the meter. If a compound meter is to be used for continuous service at a more or less uniform rate of flow, care should be taken to select a size of meter in which the " change over " point is below the flow which is usually to be measured. Compound meters will not give reliable measurement within the " change over " range; that is to say, within the range covering the change over from by-pass meter to main-line meter.

Temperature. High temperature causes the vulcanized rubber pistons of cold-water meters to expand, tending to create unusual friction or to bind the piston in its chamber. The effect is to cause slippage and under-registration or failure of the meters. Low temperature has no noticeable effect on the working parts of a meter. Freezing will of course stop the meter and possibly damage it.

Cold-water meters are not affected by temperatures up to about 80° Fahrenheit. In warm climates where the temperature of the water is liable to go above 80° Fahrenheit, meters with clearances slightly larger than ordinary should be used. Manufacturers are prepared to furnish such meters upon request.

To avoid troubles due to temperature, meters should be set in locations where they will be protected from heat and frost. In locations where hot water from the heating system may be forced back through the meter or where it may be drawn back when the mains are emptied, a check and relief valve should be installed on the outlet side of the meter.

Corrosion. The metals used in water-meter construction are all affected, more or less, by the corrosive action of the water passed through them. The action is very slow under most potable waters. Its effect is to weaken parts of the meter, particularly the teeth of the intermediate gears. It may also bind meters lying idle for long periods of time. Tuberculation of the outer case in meters of the current type may change the normal direction of flow through the meter and cause over-registration. Vulcanized rubber is but slightly affected by the corrosive action of water, and where the supply is highly corrosive vulcanized rubber intermediate gears are recommended. To avoid possible troubles due to corrosion, particularly when meters are purchased in quantity, the meter manufacturer should be furnished with the chemical and physical analysis of the water supply. Given this information, the manufacturer can use a composition of metal which in his judgment is most suitable for the particular water in question.

Suspended Matter Carried by Water. Foreign matter carried by water in suspension has different effects on different types of meters. In meters of the disc and other displacement types fine particles of suspended matter settling in the meter have a tendency to fill the voids between the piston and piston chamber and cause over-registration. Such over-registration is, however, limited and cannot generally exceed 2 per cent.

In meters of the current type the speed of the piston wheel is proportional to the velocity of flow. Any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause inaccurate registration. Accumulations of deposit always tend to cause over-registration and such over-registration is not limited, as in displacement meters.

All meters, except fire-service meters, are provided with strainers to hold back the larger particles of matter which may be carried in suspension by the water, but the meter strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive to all types of meters, and care should be exercised to prevent sand from reaching the supply mains.

The finer particles of suspended matter cannot be prevented from reaching the meter and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

Periodical Tests Necessary to Insure Proper Registration. Water meters, properly selected as to size and type, will give satisfactory service over a long period of years without attention only when operated under ideal conditions. Under ordinary conditions meters must be given a certain amount of care to secure proper registration. In most cases it is impossible to ascertain without actual test whether or not a meter which has been in service is registering within the required degree of accuracy. Consequently, in order to insure reliable meter measurement it is essential that all meters be subjected to periodical tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under average conditions the following intervals between tests should not be exceeded:

Size of Meter.	Interval Between Test Years.
$\frac{5}{8}$ in., $\frac{3}{4}$ in., and 1 in.	5
$1\frac{1}{2}$ in. and 2 in.	4
3 in.	3
4 in.	2
6 in. and larger	1

Meters of the current and compound type used for measuring unfiltered surface waters should be cleaned about once a year to keep them in good working condition. When filtered or exceptionally clean water is used, the interval between cleanings may be longer.

Best results will be obtained from current meters if they are calibrated in place, since the accuracy of these meters is affected by changes in distribution of velocities through the meter. A meter of this type calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter may register incorrectly from the start, if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error will be avoided.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces its cost.

STANDARD SPECIFICATIONS FOR COLD WATER METERS.

Adopted by New England Water Works Asssociation, March 13, 1923.
Adopted by American Water Warks Association, May 24, 1923.

Current Type.

Cases. The outer cases shall be made of bronze composition or of cast iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters shall be designed for easy removal of all interior parts, without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
$1\frac{1}{2}$	10	10 000 000
2	10	10 000 000
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000

All dials, including the initial dial, shall be sub-divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole

$\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for 1 1/2 and 2-inch Sizes. Spuds shall be either flanged or tapped, as called for. Flanges may be either of the round or oval type. If of the round type, they shall conform to the American standard of Jan. 1, 1914. If of the oval type, the drilling shall be on the horizontal axis, and in accordance with the American standard bolt circle. If the spuds are to be tapped they shall be tapped for $1\frac{1}{2}$ and 2 in. respectively, with female thread of standard pipe size, and so tapped that Briggs standard pipe thread plug gages may be screwed in by hand up to the notch on the plug.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size and so tapped that Briggs standard pipe thread plug gages may be backed into the nuts by hand, i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs standard pipe thread ring gages may be screwed on by hand flush with the face of the gage. 2 by $1\frac{1}{2}$-in. and $2\frac{1}{2}$ by 2-in. standard pipe size malleable iron bushings are to be furnished with $1\frac{1}{2}$-in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be:

Size.	Length.
$1\frac{1}{2}$ in.	$2\frac{7}{8}$ in.
2 in.	3 in.

Connections for 3, 4, 6, 8, 10 and 12-in. Sizes. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast-iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American Standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association, as far as these specifications will apply thereto. For the 3-in. size the dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connections from the face of the flanges to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, inlet and outlet coupling nuts and one or more body bolts drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Cages. Measuring cages for all meters shall be made of bronze composition and shall be self-contained and easily detached from the main body casing.

Measuring Wheels. The measuring wheel for all meters shall be made of vulcanized rubber. The measuring wheel shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers made of or coated with non-ferrous materials. The strainers shall have an effective straining area at least double that of the inlet and shall be accessible for cleaning.

Registration. The registration on the meter dial shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while

it is being tested at rates of flow within the limits specified herein under "normal test flow limits." There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size. Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
$1\frac{1}{2}$	12 to 100	5
2	16 to 175	7
3	24 to 400	10
4	40 to 700	15
6	80 to 1 600	30
8	144 to 2 800	50
10	224 to 4 375	75
12	320 to 6 400	100

Capacity. New meters shall show a loss of head not exceeding 25 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
$1\frac{1}{2}$	100
2	175
3	400
4	700
6	1 600
8	2 800
10	4 375
12	6 400

Pressure Test. Current meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Current meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Compound Type.

Definition. Compound meters are defined as those meters which consist of the combination of a main-line meter of the current or displacement type for measuring large flows and a small by-pass meter of the displacement type for measuring small flows, together with an automatic-valve mechanism for diverting the small flows through the by-pass meter.

Cases. All outer cases shall be made either of bronze composition or of cast-iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Compound meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
	Main-Line Meters.	
1½	10	10 000 000
2	10	10 000 000
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000
	By-Pass Meters.	
⅝	1	100 000
¾	10	1 000 000
1	10	1 000 000
1½	10	1 000 000
2	10	10 000 000
3	10	10 000 000

All dials, including the initial dial, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as top case, with the name of the manufacturer cast on the lid in raised letters. The same serial number shall be plainly stamped on the lid of both the by-pass and main-line meters. If required, the serial number shall also be stamped on the cases. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for 1 1/2 and 2-in. Sizes. Spuds shall be either flanged or tapped, as called for. Flanges may be either of the round or oval type. If of the round type, they shall conform to the American standard of Jan. 1, 1914. If of the oval type, the drilling shall be on the horizontal axis, and in accordance with the American standard bolt circle. If the spuds are to be tapped they shall be tapped for $1\frac{1}{2}$ and 2 in. respectively, with female thread of standard pipe size, and so tapped that Briggs standard pipe thread plug gages may be screwed in by hand up to the notch on the plug.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size and so tapped that Briggs standard pipe thread plug gages may be backed into the nuts by hand, i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs standard pipe thread ring gages may be screwed on by hand flush with the face of the gage. 2 by $1\frac{1}{2}$-in. and $2\frac{1}{2}$ by 2-in. standard pipe size malleable iron bushings are to be furnished with $1\frac{1}{2}$-in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be:

Size.	Length.
$1\frac{1}{2}$ in.	$2\frac{7}{8}$ in.
2 in.	3 in.

Connections for 3, 4, 6, 8, 10 and 12-in. Sizes. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association as far as these specifications will apply thereto. For the 3-in. size dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connections from the face of the flange to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, and one or more bolts of each cover or cap giving access to the working parts of the meter, drilled for seal wire holes. Meters having the by-pass unit in a separate housing shall have the by-pass coupling or connections drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Chambers and Cages. The measuring chambers and cages for all meters shall be made of bronze composition, and shall be self-contained and easily detached from their main body casings.

Measuring Pistons. The measuring pistons or discs of the displacement type meters shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber disc pistons shall have a metal reinforcement or a thrust roller.

Measuring Wheels. The measuring wheels of the current type meters shall be made of vulcanized rubber and shall be fitted accurately, but freely, in their chambers. The measuring wheel shall

be mounted or shall rotate on phosphor bronze or other suitable metal spindle, and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers made of or coated with non-ferrous materials. The strainers shall have an effective straining area at least double that of the inlet and shall be accessible for cleaning.

Controlling Valves. The controlling valve mechanism shall be made of bronze composition with phosphor bronze spindles, or of other suitable non-ferrous material. The valve shall cut off all flow through it when the main-line meter is not in operation and shall not bind or stick in service.

Registration. The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified under "Normal Test Flow Limits," except in the registration of flows within the "change over" from by-pass meter to main-line meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change over" shall not exceed the figures given in the following table:

Size, Inches.	Gallons per Minute.
1½	20
2	32
3	63
4	100
6	200
8	320
10	460
12	620

The beginning of the "change over" is when the accuracy of registration falls below 97 per cent. due to the automatic valve mechanism, and the end of the "change over" is when the accuracy of registration again reaches 97 per cent.

There shall not be less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size Main Meter, Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
$1\frac{1}{2}$	2 to 100	$\frac{1}{2}$
2	2 to 160	$\frac{1}{2}$
3	4 to 315	1
4	6 to 500	$1\frac{1}{2}$
6	10 to 1 000	3
8	16 to 1 600	4
10	32 to 2 300	8
12	32 to 3 100	14

Capacity. New meters shall show a loss of head not exceeding 25 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
$1\frac{1}{2}$	100
2	160
3	315
4	500
6	1 000
8	1 600
10	2 300
12	3 100

Pressure Test. Compound meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Compound meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Fire Service Type.

Definition. Meters for fire service are defined as those meters which consist of the combination of a main-line meter of the proportional type for measuring large flows, and a small by-pass meter of the displacement type for measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter; the combination affording a clear passage through the meter when the main-line valve is raised from its seat.

Cases. All outer cases shall be made either of bronze composition or of cast iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connectons to the pipe line.

External Bolts. All external bolts shall be made of bronze, or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
	Main-Line Meters.	
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000
	By-Pass Meters.	
$1\frac{1}{2}$	10	1 000 000
2	10	10 000 000
3	10	10 000 000
4	100	100 000 000
6	100	100 000 000

All dials, including the initial dial, shall be sub-divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as top case, with the name of the manufacturer cast on the lid in raised letters. The same serial number shall be plainly stamped on the lid of both the by-pass and main-line meters. If required, the serial number shall also be stamped on the cases. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American Standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association, as far as these specifications will apply thereto. For the 3-in. size dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connection from the face of the flange to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, and one or more bolts of each cover or cap giving access to the working parts of the meter, drilled for seal wire holes. Meters having the by-pass unit in a separate housing shall have the by-pass coupling

or connections drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Chambers and Cages. The measuring chambers and cages for all meters shall be made of bronze composition, and shall be self-contained and easily detached from their main body casings.

Measuring Pistons. The measuring pistons or discs of the displacement type meters shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber disc pistons shall have a metal reinforcement or a thrust roller.

Measuring Wheels. The measuring wheels of the current type meters shall be made of vulcanized rubber and shall be fitted accurately, but freely, in their chambers. The measuring wheel shall be mounted or shall rotate on phosphor bronze or other suitable metal spindle, and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Main Line Controlling Valves. The controlling valve shall be either of the atmospheric or mechanical type, in which the initial resistance to opening practically disappears after opening. The atmospheric valve shall open under a difference in pressure, between the inlet and outlet sides of the meter, not exceeding 6 per cent. of the available pressure. The mechanical valve shall open under a difference in pressure not exceeding 4 lb. to the sq. in.

The controlling valve mechanism shall be made of bronze composition with phosphor bronze spindles or of other suitable non-ferrous materials. The valve shall cut off all flow through it when the main-line meter is not in operation. It shall effectively prevent backflow and shall not bind or stick in service.

By-Pass Check Valve. All meters shall be provided with check valves on the by-passes. The check valve mechanism shall be made of bronze composition or of other suitable non-ferrous material. They shall effectively prevent backflow and shall not bind or stick in service.

Registration. Registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified under "Normal Test Flow Limits," except in the registration of flows within the "change over" from by-pass meter to the main-line meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change over" shall not exceed the figures given in the following table:

Sizes, Inches.	Gallons per Minute.
3	63
4	100
6	200
8	320
10	460
12	620

The beginning of the "change over" is when the accuracy of registration falls below 97 per cent., due to the automatic valve mechanism, and the end of the "change over" is when the accuracy of registration again reaches 97 per cent.

There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size, Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
3	8 to 400	2
4	8 to 700	2
6	16 to 1 600	4
8	28 to 2 800	7
10	48 to 4 375	12
12	48 to 6 400	12

Capacity. New meters shall show a loss of head not exceeding 4 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
3	400
4	700
6	1 600
8	2 800
10	4 375
12	6 400

Pressure Test. Fire service meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Fire service meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

HERBERT M. TUCKER.

Herbert Marion Tucker was born at Northfield, Vt., in 1867, and died at Lebanon, N. H., May 23, 1922, the adopted son of Mr. and Mrs. Franklin Tucker, of Northfield, who later removed to Lebanon.

His education was that received in the public schools of Lebanon. When a young man he went to Montana, where he had five years of ranch life, ever a most appealing thing to him. He then lived a few years in Providence, R. I., as a telephone linesman, subsequently returning to Lebanon as an employee of the Lebanon Electric Light Company. All the way, from the bottom to the top, did he find himself promoted by his company, until he became general manager. Some seven years before his death his company merged with the Grafton County Light and Power Company, of which he very soon became general manager.

He served Lebanon for several years as one of its fire-wards, a portion of the time being the chief of the fire department.

He also served the town one session as a member of the legislature of the state.

He leaves a widow and a daughter.

He was a member of the Masonic and Odd Fellows organizations.

In his work he was a discreet enthusiast. Seemingly nothing ever tired him. He was almost a model manager, both from the standpoint of his employers and the general public. The people whom he served had faith in him. This confidence was never violated. He did not know how to be mean or to be little. But he did know how to be honest, fair, trustworthy. That was the life he lived. He became the very soul of his corporation, a splendid factor in the life of his community, and when he died all deeply mourned. Surely there can be no higher eulogy than this.

Percy R. Sanders,
Committee.

WILLIAM HENRY PITMAN.

Born, January 11, 1851. Died, May 9, 1923.

William Henry Pitman was born in Fall River, Massachusetts, January 11, 1851. When a youth his family moved to New Bedford, where he attended the public schools, graduating from the High School in 1867. He came from a family which has been prominent in New England since 1663. Mr. Pitman never married.

In 1870 he became a clerk in the New Bedford Institution for Savings, where he advanced in positions of trust for nineteen years. In 1889 he was elected Treasurer of the New Bedford Five Cents Savings Bank, which position he held until January, 1923, when he resigned on account of ill health. Following his resignation, he was elected assistant to the President of the bank, holding that position at the time of his death. He was accepted as an authority in Savings Bank finance through more than half a century.

He held many positions of responsibility in New Bedford, including three years in the City Council, nineteen years on the School Board, and six years as a Commissioner of Sinking Funds.

He was a member of the New Bedford Water Board from 1906 until his death.

He has been a member of this Association since March 11, 1908.

As a private citizen and public official, he always stood out as an example of faithful and conscientious performance of duty and will be greatly missed by a large circle of friends and relatives.

For the Committee,

Frederick H. Taber,
S. H. Taylor.

PROCEEDINGS.

February Meeting.

Boston City Club,
Tuesday, February 13, 1923.

The President, Mr. Percy R. Sanders, presided.

The Secretary reported that the following had been elected members of the Association by the Executive Committee at their forenoon meeting: George G. Weeks, Trustee, Kennebec Water District, Fairfield, Me.; Charles E. Kendall, Retired Water Commission, Winchester, Mass.; Dexter P. Cooper, Hydraulic and Sanitary Engineer, Buffalo, N. Y.; Harry N. Lendall, Associate Professor of Civil Engineering, New Brunswick, N. J.; Horace J. Cook, engaged in water-works construction and operation, Auburn, Me.; Daniel M. Sullivan, Engineer of High Pressure Fire Service, Water Division, Boston. — 6.

Report of Committee on Laws relating to Financing Water Works.

PRESENTED BY CHARLES W. SHERMAN.

To the New England Water Works Association: The Committee on Massachusetts Laws relating to Financing Municipal Water Works submits the following report of progress:

Bill Introduced in Legislature. The January meeting of the Association authorized the Committee to introduce a bill on behalf of the Association looking towards the accomplishment of such portions of its program as the Committee thought practicable. After careful consideration the Committee decided to introduce a bill which would amend the general laws, *first,* by striking out the clause containing the 5-year limit on bonds for water-works extensions and *second,* by providing for a 30-year borrowing period for practically all major items of enlargement or improvement of water-works systems; — leaving for the future the other matters in which it is believed changes in legislation or new laws are desirable. The bill introduced, which is numbered as *House Bill No. 661* and has been referred to the Committee on Municipal Finance,* is as follows:

> Section 1. Section eight of chapter 44 of the Revised Laws, as amended by section eleven, chapter four hundred and eighty-six of the acts of nineteen hundred and twenty-one, is hereby further amended by striking out the whole of said clause (4) and inserting in place thereof the following: —

* The members of this committee are as follows:

Senators: John Halliwell, New Bedford; Alvan E. Bliss, Malden; George D. Chamberlain, Springfield; Edward J. Cox, Boston.

Representatives: George J. Bates, Salem; George H. Newhall, Lynn; Ernest A. Larocque, Fall River; Andrew P. Doyle, New Bedford; James M. Hunnewell, Boston; Albert A. Sutherland, Boston; Elmer E. Dawson, Winthrop; John E. Beck, Chelsea; Michael E. Jordan, Lawrence; Charles H. Slowey, Lowell; Valmore P. Tetreault, Southbridge.

(4) For the extension of water mains or replacing inadequate mains by pipes of larger size; for constructing, extending, enlarging or replacing pumping stations, pumping equipment, filtration plants or equipment; for the construction or enlargement of reservoirs, or standpipes; for the construction of wells, collecting galleries, intakes, conduits and aqueducts; and for the purchase and installation of water meters; thirty years.

Section 2. This act shall take effect upon its passage.

The Committee has just announced the date of hearing on this bill, February 21. It is obviously desirable that as many as possible of the Massachusetts members of the Association and other persons interested in the passage of this legislation should attend the hearing and should request their senators and representatives to record themselves in favor of the bill, and later, should the bill be recommended by the Committee, urge its passage by the legislature.

Other Legislation Pending. Although foreign to the scope of this Committee's work, there are other items of legislation pending in the general court, which it may not be out of place to call to the attention of the Association. Among these are the following:

House Bill 352 "to provide access for the public to great ponds." This bill is before the Committee on Harbors and Public Lands and date for hearing is February 16. The dangers of making access to great ponds used for water supply any easier than at present are, of course, obvious.

As an instance of the dangers of such access, it may be noted that *House Bill 652*, to authorize the inhabitants of Marlboro to fish in Sudbury Reservoir, was before the Committee on Metropolitan Affairs which reported adversely. Upon the vote being taken in the House there was a margin of but two votes (102 to 100) in sustaining the Committee. Obviously, therefore, the dangers of legislation permitting fishing in our water-supply reservoirs are still such as to give serious concern to those charged with the protection of the supplies.

House Bill 644 "prohibiting the shutting off of water by cities and towns" is before the Committee on Legal Affairs and date for hearing is also February 21. This bill would prohibit the shutting off of water for non-payment of water rates, but as an alternative would make water rates a lien upon the real estate. While the latter provision is desirable, it should not be attained at the expense of the right to shut off water.

House Bills 20 and 181, which are before the Joint Committee on the Judiciary and upon which hearings were held on January 31, would make water rates a lien upon the property. The former applies to the city of Boston only, and the latter to the State as a whole.

House Bills 776 and 777, which are before the Committee on Public Safety and upon which hearings are announced for February 15, provide for inspection of all reservoir and mill dams within the state.

Respectfully submitted,

BERTRAM BREWER
LEONARD METCALF
A. R. HATHAWAY
CHARLES W. SHERMAN
Committee.

FEBRUARY 13, 1923.

The President. This, as I understand it, is simply a report of progress.

I was interested in looking at *House Bills 20* and *181*. What you do in Massachusetts of course has no bearing on New Hampshire, but I see that the city of Boston is trying to get a bill through making water rates a lien on the property. I was somewhat surprised in looking through the laws of New Hampshire recently to see that the city of Portsmouth has done just that same thing. We tried to get a bill through the Legislature making it state wide, but it seems they got busy and had a bill passed through simply for the city of Portsmouth.

The subject of a satisfactory return for water sold to takers owning more than one house upon a lot or parcel, and who are supplied with water taken through a single meter located on the property, was discussed by Messrs. A. A. Dickerman, H. J. Goodale, Reeves J. Newsom, Henry V. Macksey, George W. Batchelder, Stephen H. Taylor, William F. Sullivan and Henry T. Gidley.

Mr. Philip W. Ayers, Forester of the Society for the Protection of New Hampshire Forests, gave a talk illustrated with the stereopticon, on "Reforestation of Water-sheds."

Messrs. Alexander Orr and Richard A. Hale made some remarks on this subject. On motion of Mr. Samuel E. Killam, Mr. Ayers was given a rising vote of thanks.

A paper on "The Application of a Booster Pump to a Gravity System of Water Supply," was read by George F. Merrill, Superintendent Water Works, Greenfield, Mass. Mr. Merrill also showed some stereopticon views.

President Sanders and Mr. John L. Howard took part in the discussion.

(*Adjourned.*)

March Meeting.

City Club, Boston,
Tuesday, March 13, 1923.

Vice President George A. Carpenter in the chair.

The Secretary announced that the Executive Committee had elected to membership Harry E. Holmes, Resident Engineer, State Department of Public Health, Malden, Mass.

On motion of Mr. Frank A. Marston, it was voted to authorize the President to appoint a Nominating Committee to nominate officers for the annual meeting.

The Association voted unanimously to approve the actions of the Executive Committee in discharging the following committees:

Committee on Standards of Purity for Water.

Committee to Consider and Collect Data on Assessments of Cost of Main Pipe Extensions and the Relation of New Street Layouts or Connections therewith.

Committee on Methods of Extending the Influence of the Association.

Committee on Statistics of Water Purification Plants.

Committee on Activities and Program of the Association.

Committee on Leakage of Pipe Joints.

Committee on Proposed Standard Schedule for Grading Cities and Towns of the United States with Reference to Fire Defense and Physical Condition.

Committee on Uniform Accounting.

Mr. Charles W. Sherman submitted the final report of the Joint Committee of the American and New England Water Works Associations on Standard Specifications for Water Meters.

It was voted that the report be accepted, that the Standard Specifications be adopted "when and if approved and adopted by the American Association" and that the committee be discharged.

On motion of Mr. Caleb M. Saville a rising vote of thanks was given Mr. William W. Brush and Mr. Edward Neubling for their work on the Standard Specifications for Water Meters.

Dr. Charles E. Lucke of Columbia University, gave a talk on The Diesel Oil Engine. Dr. Lucke's remarks were supplemented as to special features by Rodney D. Hall of the Worthington Pump Machinery Corporation, by Mr. H. M. Chase and by Mr. M. Spillman. Messrs. Vernon F. West, Frank A. Marston, Samuel A. Agnew, A. O. Doane and Frank A. Barbour took part in the discussion.

Mr. Frank A. Barbour. Mr. Chairman, I am sure we all feel that we have had a wonderfully profitable afternoon. I came to this meeting looking forward to hearing Dr. Lucke speak, having heard him speak before, but he has gone beyond my anticipations. I think this afternoon has proof of the value of having the representatives of commercial organizations speak to an Association such as this. The engineers who are right in their subjects know far more than any of the consultants can possibly know.

I rise to move a vote of thanks to the speakers of the afternoon.

(The motion was duly seconded and unanimously carried.)

(*Adjourned.*)

Photo by The Kimball Studio, Concord, N. H.

PERCY R. SANDERS,
President of the New England Water Works Association,
1923.

New England Water Works Association

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME ADDITIONS TO NEW ENGLAND WATER WORKS PLANTS.

BY ALLEN HAZEN.*

[*Read by Malcom Pirnie, September 19, 1923.*]

I propose to give you to-day a very brief outline of some of the waterworks construction in New England and just over the line in New York State, but without going into details.

New Britain.

Several years ago a plan for the development of the water-supply system was worked out on a scale sufficient to serve the city for many years. When carried out this will result in the complete development of the present water resources.

The plan is unusual in that no good storage site was found to which most of the water would come in a natural way. The plan is to build a large impounding reservoir on an excellent site but with a very small catchment area, and to take the major part of the flood flows from the other areas to it. In this way a practicable scheme was worked out for complete development of these valuable resources. The cost of carrying out even the first installment of this program will be large, and postponement as far as it can be done with safety will make the financial arrangements easier.

In making borings for dam sites, great masses of sand were found in one of the valleys. To build a dam on this sand was impracticable, but it was thought that it might be possible to develop a ground water supply in this location, taking advantage of the natural underground storage in this valley. In this way an addition to the water available in dry times could be obtained that would permit the construction of the main storage reservoir to be postponed for several years.

Some of the works built in this way could be arranged to be part of the permanent construction, but any of it that it might be necessary to discard in future development would have been more than made good in the saving in interest on the cost of the delayed construction.

* Consulting Engineer, New York City.

Accordingly, the city authorized the construction of an underground supply of this kind, and the work has been carried out and the supply tested during the present season. There are twenty wells, 8 in. in diameter, averaging 40 to 45 ft. deep. The position of the wells was determined, first, by very numerous test borings; and second, during construction by pulling up and discarding all wells that did not show favorable results in actual tests. Every one of the twenty wells is therefore believed to be a good one. The Cook strainers are 15 ft. long, 8 in. in diameter, and the slots for the most part are 0.05 in. wide, but some of them are 0.06 in. The slot opening was made as great as the sand would stand. In a few instances, sand was encountered so fine that it continued to come into the wells in quantity, and these wells were abandoned and the strainers pulled. In most cases a considerable quantity of sand entered the well in the early testing and was pumped out until a condition of stability was obtained.

In this testing, an arrangement was used for giving violent back-and-fourth agitation in connection with the pumping, and this was continued until the water came continuously clear and until all fine sand had been removed from the bottom of the well.

The water from these wells is taken into a caisson well, which is covered, 50 ft. in diameter and 30 ft. deep, which itself on test yielded about 1 m.g.d. The use of this well is to insure the entire absence of sand and air in the water taken by the pump.

In driving the wells a 12-in. casing was first driven to the full depth. The strainer and permanent well pipe were placed in it and the 12-in. pipe was then drawn. Sometimes coarse sand was placed in the space before drawing the 12-in. pipe. Independent 4-in. suctions are used in each well, and the connections are arranged so that each suction can be easily removed and the well tested and cleaned, and this can be done with the well shut off and with the rest of the plant in service. A concrete box is built about the head of each well, giving convenient access to facilitate these operations and to exclude surface water. The main suction pipe, laid well below the ground level is of cast-iron pipe with bell joints, calked with lead wool by a pneumatic hammer, and made absolutely tight under air pressure. This is laid with a very slight upgrade to a summit after passing which it drops almost to the bottom of the caisson well, acting as a siphon when the water level is depressed. An air pump attached to the highest point keeps it clear of air.

The water is pumped by a horizontal duplex pump driven by a 150 h.p. Diesel engine. It has a capacity of 3 m.g.d. against a head of 250 ft.

The plant has been able to operate continuously at capacity during the present very dry season, and its use has perhaps prevented a water shortage in New Britain. The water is clear, cool, soft and free from iron.

The cost of the new works has been very moderate. The bills are not yet all paid. Present indications are that, including land and all expenses, it will not exceed $175 000.

Mr. Joseph D. Williams is City Engineer and has immediate charge of the construction work. Mr. Charles R. Bettes, who has had long experience in building and operating well supplies, helped in the development of the plans.

SPRINGFIELD.

In the fourteen years since the Springfield Little River System was put in service the water business in Springfield has almost doubled. The output has not increased in quite that ratio because in the beginning the system was only partially metered, and during the early years with metering there was an actual reduction in output.

Springfield has grown more rapidly and continuously than any other city in Massachusetts. In addition, the policy has been followed of supplying water to neighboring communities at wholesale.

The underlying thought in doing this was that it would cost these communities at least twice as much to get corresponding service for themselves as it would cost the city of Springfield to supply them.

It would be fair to divide this advantage equally. With this done a price could be fixed that would yield Springfield a profit of 50 per cent. on all the business done, and the towns would still be getting water 25 per cent. cheaper than they could otherwise get it. These figures are not precise but they illustrate clearly the controlling thought in the business.

If the cost of the service is estimated, taking into account all the costs that there are, including interest and depreciation, and basing the rate on the actual output rather than on the rated capacity, and 50 per cent. is added, the estimate of the fair price for these takers is reached. No water-supply system will suffer by taking additional business that carries a 50 per cent. profit.

This general policy has been followed and has resulted in substantial additions to the drafts and to the required capacity.

A water-works system consists of many parts and these parts do not all come to the limit of their capacity at exactly the same time. This is fortunate for it permits the additions to be built in installments spread over a term of years.

In this case, the Little River run-off has turned out to be greater than expected; and as the storage was originally provided on a liberal scale, the source will safely carry something over 15 mil. gal. originally assumed as the capacity of the first installment. With complete development about three times this quantity will be obtained.

The pipe lines, built of lock-bar steel, coated with specially selected and prepared coal tar, will carry more water than was estimated in advance for riveted steel pipe of their present age and will therefore serve a few years longer.

The filters need enlarging first. The water, which, in dry times, is mainly drawn from the Borden Brook Reservoir on a tributary is rather

more difficult to treat than was anticipated before the works were built. There has been a much larger load of organic matter in it to be removed, and this has made chemical treatment necessary. Coagulation has been employed, and the load upon the filters has been correspondingly greater.

Notwithstanding the greater load upon the purification works, the present plant has turned out water of the highest quality uninterruptedly for the whole period of its use, and the operating costs, notwithstanding some bothersome conditions, have been on a moderate scale that has been seldom reached in water purification plants in this country.

The present plant consists of a coagulating basin holding 40 mil. gal., and three acres of covered sand filters, and the present rate of output is frequently in excess of the 15 mil. gal. per day, for which the plant was built.

Doubling the capacity of the filter plant is thus the first logical step in enlarging the plant, and this is now being undertaken.

In doing this the equipment for applying and mixing the coagulant with the water will be improved. Baffles are to be built in the very large coagulating basin which was fortunately a part of the original plant and the sand filters are to be duplicated.

Before deciding to duplicate the present plant, several alternate arrangements were considered. Among these may be mentioned placing scrubbers in advance of the sand filters to lighten the load upon them. This will not be done because present and prospective operating costs are so moderate that it would never be possible to save from them amounts to compensate for the cost of the scrubbers. With the local water and with the chemical treatment that has been employed and that has been found satisfactory, it is not thought that satisfactory purification of the water after treatment by mechanical filters would be possible. If such filters were used a continuous and heavier dose of coagulant would be essential and the operating cost correspondingly increased.

The present plant has produced water of the highest quality and with a low operating cost, and it was not apparent that any more advantageous arrangements could be made in extending it.

It is also taken into account that in the near future a very large storage reservoir will be built upon the main stream and that, with the storage of the whole supply in this reservoir, a considerable improvement in average quality of water entering the plant may be expected.

The ten-year average color of the water entering the plant is 38. This will be reduced to a much lower amount after the large proposed Cobble Mountain reservoir is in use. Fifteen years ago, before the plant was built, it was assumed that when Cobble Mountain reservoir was built and complete storage obtained, that no further use of coagulant would be necessary. With present ideas with regard to color and color removal, this view must be modified, but it still appears probable that the plant

with sand filters of full efficiency may be operated without coagulant for a considerable and increasing proportion of the time in the future.

Mr. E. E. Lochridge is Chief Engineer of the Springfield Water Works and has supervision of the construction.

PROVIDENCE.

A general description of the Providence work has already been presented by the Chief Engineer, Frank E. Winsor, Vol. 36, p. 323. What I shall say relates only to the filters which are proposed.

The water will be obtained from a storage reservoir that will be large in size and the water before filtering is expected to be of good quality. On the other hand the color records of the last seven years have indicated a distinctly higher color of the river water as it flows than was anticipated in the earlier studies. Allowing for such decolorization in the storage reservoir as is to be expected it appears probable that there will be color above allowable limits in the reservoir water for periods, the length and frequency of which cannot be closely estimated. The filters must therefore be capable of dealing adequately with considerable amounts of color as well as with the tastes and odors and other impurities to be expected in a reservoir water. The color to be dealt with on present evidence will be considerably higher at Providence than at Springfield.

The question of whether to use sand or mechanical filters has been studied at considerable length. The higher color of the raw water was one important element in the decision to use mechanical filters; another was the unusual difficulty of the site. Several sites for sand filters were studied. The material in each case consisted of sand of various grades filled with boulders, some of them weighing many tons. Excavating such material and bringing it to a uniform foundation grade and making the bottom water tight presented unusual difficulties and put an added burden on the construction of sand filters.

The water is unusually soft and it was felt that the use of mechanical filters with only a relatively short coagulation period would be likely to result in red water troubles, to the corrosion of the iron and lead service pipes, and to supplementary precipitation of hydrate of alumina in the distribution and service pipes.

The best means of avoiding these conditions at present available seems to be to use a very large coagulating basin capacity. The chemists have been working for many years on some means of accelerating the reactions, but thus far practical experience supports the idea that a large basin is the most efficient means of securing a reasonably stable and quiet water.

A valley has been found where such a basin could be constructed in connection with the Providence filters. This will hold more than a day's

supply at the ultimate rate possible from this source and several days' supply at the rates of early years. The adopted plan therefore is to give the water chemical treatment followed by passage through a very large coagulating basin thoroughly baffled, thence passing to mechanical filters.

In the design of the mechanical filters, there will be a number of novel features to adapt them to the conditions to be anticipated in this case.

Preliminary studies have been made for types of filters, combining as far as possible the advantages of both sand filters and mechanical filters, but some of these ideas may require further development before they can be safely applied in so large a plant.

Aëration of the water both before and after filtration is proposed to reduce tastes and odors and also to remove carbonic acid and thus to make the water less active in the pipes.

The Providence water now supplied has been somewhat active. Corrosion of lead pipes and fear of lead poisoning have been much discussed. Lime has been used to reduce this tendency for several years. This phase of the matter is most important and every effort will be made to turn out a water from the new works that is satisfactory in all respects and that is reasonably quiet in the pipes.

The construction of the new filters will be in charge of Mr. Winsor and his assistants.

Poughkeepsie and Albany.

I am now going slightly beyond the boundaries of New England to say a few words about plants of interest, operating under very different conditions. Poughkeepsie and Albany both take water from the highly polluted Hudson River, and it must be most carefully filtered to remove its disease-producing qualities. This is an entirely different problem from those presented in the plants previously mentioned. In both cases, gravity supplies are possible, and will no doubt be ultimately used, but in the meantime, the filter plants must be kept up to standard.

The Hudson River is so highly polluted that it is questionable whether single filtration of any type is capable of producing water meeting present exacting standards with a proper factor of safety. At any rate double filtration has been used at both of these plants for some years, and is now regarded as a necessary part of the procedure.

The water first receives chemical treatment, then goes through coagulating basins and passes to scrubbers, which are mechanical filters with only a little of the equipment omitted, and then passes to sand filters. The sand filters in each case represent the earlier plant and the scrubbers are more recent additions.

At Poughkeepsie the scrubbers were added as a war measure when increased capacity was urgently needed and when the old sand filters were having trouble in maintaining service. Since they have been used, it has only been necessary to clean the sand filters about once a year. The

scrubbers do the heavy end of the work and the sand filters finish it and remove whatever materials come through the scrubbers, including tastes and odors and at times a certain amount of hydrate of alumina. The water is aërated once only between the two sets of filters.

The Poughkeepsie plant is ample in capacity at every point for present output and has worked easily with the production of water of such uniformly good quality that the residents of Poughkeepsie are not interested at present in changing the source of supply.

During the present year a new 5-mil.-gal. covered reservoir is being built to give 20 lb. needed additional pressure and to permit water to be delivered in the city of the same excellent quality as that leaving the filters.

The old open reservoir in which objectionable algæ growths sometimes took place will be held as an emergency reserve to be connected with the system only in case of conflagration. A new loop of 24-in. pipe extending all the way from the source of supply around the business district of the city to the new reservoir has been provided and with a few main feeders will give ample distributing capacity for years to come.

At Albany, a somewhat similar general filtering arrangement was installed earlier, and has for years made operation possible, but can be improved.

One of the undesirable conditions has been that the water was pumped from the coagulating basin to the scrubbers. This has broken up the floc and has made efficient operation impossible. The filter sand in the scrubbers was too coarse and had become very dirty. The scrubbers were demoralized; floc passed entirely through them, and passing the sand filters clogged them rapidly until they could not be adequately cleaned, and it has been thought necessary to by-pass some of the partially treated water to the city.

Chlorine treatment has saved, or nearly saved, the situation from a hygienic standpoint, but the results have not been satisfactory in other respects.

It is proposed to reconstruct the scrubbers, bringing them back to standard condition; to build a new covered coagulating basin at higher level so that the water will flow from it to the scrubbers by gravity, slowly and without agitation, and to use the present coagulating basin as an intermediate receiving basin between the two sets of filters. Other changes will be needed, and when these are carried out, it is hoped that operating conditions may be brought fully up to the highest standard and maintained as long as the present source of supply is used.

It is to be noted that tests during the recent period of very low flow in the Hudson River have shown at Albany a much heavier load of fresh putrescible organic matter from sewage in the water, than has been found at Poughkeepsie and the water is correspondingly more difficult to treat at such times.

It is thought at Albany that even though a gravity supply, for which there are excellent opportunities, should be introduced in a few years, the need of better water was so urgent that the present filter plant should be put in order in any event.

Mr. F. A. Raven is Commissioner of Public Works at Albany, and Mr. Thomas F. Lawlor, Superintendent of Public Works at Poughkeepsie.

This, I believe, completes a very brief description of some of the new works under way that may be of interest.

Discussion.

Mr. J. M. Diven.* It might be interesting to know that the Poughkeepsie plant was, I believe, the original filtration plant in the United States.

Mr. M. N. Baker.† I might supplement that last remark by giving a little additional information. The late James P. Kirkwood, who was sent to Europe to investigate filtration in 1866 by the city of St. Louis, and who recommended slow sand filters for St. Louis, did not have the opportunity to build such a plant there. Mr. Kirkwood was fifty years ahead of the times, so far as St. Louis was concerned, for that city relied upon sedimentation until 1915, when it put in operation the mechanical filtration plant which many of you know about. In view of the muddy character of the St. Louis water supply, it was probably fortunate that the city did not build slow sand filters. But Poughkeepsie, New York, with the comparatively clear waters of the Hudson River as its supply, did reap the advantage of what Mr. Kirkwood learned about slow sand filtration in Europe, and particularly in England, and built a slow sand filtration plant in 1870, with Mr. Kirkwood as engineer. In 1874–75, Hudson, N. Y., also built slow sand filters, with J. B. G. Rand and J. H. Enigh as engineers. It may be added that Mr. Kirkwood's report on his studies of water treatment abroad was published in book form in 1869, with the title, "The Purification of River Waters." So far as I know, this was for many years the only book on water purification available in the English, if indeed in any language.

Mr. J. Frederick Jackson.‡ I would like to ask Mr. Pirnie if he thinks that there is any probability of their resorting to the very novel feature which was proposed when this plant was under design, of flooding the surface of the ground over the wells in order to increase the supply? I believe the plant has been in continuous operation in pumping, and as the records indicate, there has not yet been any necessity of resorting to that.

* Secretary, American Water Works Association.

† Associate Editor, *Engineering News-Record.*

‡ Director, Bureau of Engineering, State Department of Health, Connecticut

Mr. Pirnie. Experience during the past dry season indicates that sufficient water for the present can be pumped from the wells without resorting to artificial methods of increasing the ground water supply. The depth of porous material in this valley is fairly shallow. This gave reason for doubt as to whether or not there would be sufficient cross-sectional area of flow to supply the wells when the ground water level was depressed by continued pumping.

Two methods of increasing the amount of ground water in the immediate vicinity of the wells were therefore outlined. One was that mentioned of flooding the surface of the ground about the wells, and the other was the construction of a shallow canal in the sandy material paralleling the wells with provisions for cleaning the sand at intervals. Both the flooding of the ground and the canal would be supplied from the streams in the valley. Experience so far with the supply indicates that it will not be necessary to resort to either of these measures at present. They may be carried out, however, if they are found to be necessary when larger quantities of water are required in the future.

Mr. W. L. Hatch.* I want to say, in regard to the plant at New Britain, that we have been operating at our full capacity of 3 mil. a day throughout the summer, more as a test of what could be done and making sure that everything would run all right, than from actual necessity, as we have our main reservoir nearly full at present. We are now operating at 1-mil. capacity, having one 8-hr. force a day, simply taking care of our high service reservoir, which cannot be operated from our main plant. During the five weeks that it was operated in July and thereabouts at 24-hr. service the water maintained its level, after dropping down some 5 or 6 ft. That is, the ground water, after going down 5 or 6 ft., remained at that level through the entire time, and since it is being run one-third of the time the water is somewhat higher in the ground. We see no evidence whatever that we will not have an ample supply, as this has been the driest season we have had in a great many years in our vicinity.

* Chairman, Board of Water Commissioners, New Britain, Conn.

THE SELECTION OF PUMPING EQUIPMENT FROM THE STANDPOINT OF STATION ECONOMY.

BY FRANK A. MAZZUR.*

[*Read September 19, 1923.*]

In preparing this paper on the selection of pumping equipment, I had in mind the problem that comes up sooner or later before every water-works manager, in the selection of a pumping unit on account of the increased demand for water, or from existing equipment having become used up or obsolete.

Up to a few years ago this question would have been confined to simply the capacity and type of a steam-driven unit but developments in recent years have made it necessary to make a study of the possibilities of purchased electric power, and oil engines as well as the usual steam-driven pumps.

The two points of paramount importance are dependability and operating costs, and in a pumping plant furnishing the water supply for a community, dependability is by far the greater of these two points. In making the comparisons of the various types of apparatus I have based the figures on units of about 3 000 000-gal. capacity in twenty-four hrs., as the majority of pumping plants in New England are of this size or smaller.

The crank and fly-wheel pumping engine is without question the most economical in the use of steam, a unit of this size being able to deliver about 124 000 000 ft. lb. per 1 000 lb. of steam under the ordinary steam conditions found in existing pumping stations. They also have an excellent record for dependability and low cost of upkeep. Their price, however, is high compared to other types of pumping equipment, but even with its high cost this type of steam-driven pump is a favorite where the maximum steam economy is the main consideration. However, a great many installations of pumping equipment are made for stand-by service or peak-load conditions, and as an addition to an existing plant consisting of buildings, boiler equipment, etc.

In making our comparisons we are considering only a plant having good boiler equipment, etc., and it is an additional installation of this kind that we are taking up in this paper, and not the building of a new plant where no previous investment has to be taken into account.

A good many of the installations put in during the past few years have been made where the existing equipment has been of sufficient or nearly sufficient capacity but of obsolete type. Let us consider a plant equipped

* Mechanical Engineer, Boston, Mass.

with two direct-acting compound pumps, one of which is to be replaced with a pump of somewhat greater capacity. As the direct-acting pumps even when new, have a very poor duty compared with what we look for at the present time, the new unit would naturally be of a different type. In the event of the available space being able to accommodate a crank and fly-wheel engine without any great alterations in the building, this type of engine should undoubtedly receive serious consideration.

However, it may be that to install a crank and fly-wheel pumping engine would entail an extensive addition to the building the cost of which added to the high cost of the pumping engine would bring the fixed charges on the investment up to a point where the total yearly cost would be greater than if a unit of different type and poorer duty, but of much lower cost were installed.

Turbine Drive.

The turbine-driven centrifugal pump has the advantage of low first cost and very small space requirements compared with the crank and fly-wheel pumping engine. The duty, however, is by no means as good, but as mentioned above this is very often more than offset by its lower cost. I mentioned previously a duty of about 124 000 000 ft. lb. per 1 000 lb. of steam for the crank and fly-wheel engine. Under the same steam conditions a duty of about 100 000 000 ft. lb. can be obtained with the turbine-driven centrifugal pump. Before making the actual detailed comparison I would like to point out some of the advantages of this type of unit. In addition to the small space requirements a very small foundation is needed. The unit is practically self contained, and the arrangements of suction and discharge pipes can be worked out in a very simple and inexpensive manner.

Now let us assume that instead of replacing an obsolete unit with one designed for every-day service at best economy, we have the case of a plant equipped with an economical pumping engine for regular service, and a stand-by unit which is either too small in capacity for the increasing demand, or is worn out or obsolete. In this case a steam turbine-driven centrifugal pump offers the best solution of the problem, for the space requirements of this pump and its appurtenances are such as to require no more room than is occupied by a direct-acting duplex pump of considerably less capacity. Moreover, the price is as low as any dependable pumping equipment and the economy is such that if operated for long periods, the operating costs would not be so very much above that of the most economical type of steam-driven pump that they might have in for their main unit.

Electric Drive.

In the foregoing descriptions of pumping apparatus steam drive only has been considered and in many cases there is no reason to consider any other source of power. Where the boiler plant and all of the steam machinery is in good condition it is very difficult to show where a saving can be

made by reverting to electric drive, especially in a plant of such size as to require only one man on duty. This one man will be required in any event and while perhaps a small saving may be effected from the fact that in operating an electrical unit a licensed engineer is not required, it is always necessary to have an intelligent man in charge.

In the way of electrically-driven apparatus there are two types of pumps that are usually considered. These are the plunger pump geared to an electric motor and the centrifugal pump direct connected to the driving motor.

The comparison of these two types of pump is very similar to the comparison of the crank and fly-wheel pumping engine and the turbine-driven centrifugal. The horizontal plunger pump of 3 000 000-gal. capacity would practically be the same pumping unit that would be driven by the crank and fly-wheel engine, and the direct-connected centrifugal pump would be the same pump as the one driven by the geared steam turbine. As in the case of the steam drive it is simply a question of fixed charges and operating costs. The guaranteed pump efficiency of the horizontal plunger-type pump of this size is about 90 per cent. and the efficiency of the centrifugal pump about 80 per cent., and in the tabulation of operating costs which we will come to later these two types of electrically-driven pumps run surprisingly close together in fixed charges and the cost of electric current.

Oil Engine Drive.

The methods of driving the steam and electrically-driven pumps considered so far are very familiar to all of us, but there is another form of drive that is making headway in pumping engine service, and the economy of this form of drive is bringing it rapidly to the front.

The oil engine of the Diesel type has been known for quite a number of years and up to the time of the war had been used with considerable success in many forms of industry. It did not receive much consideration in installations for water supply, as dependability could not be sacrificed for economy. During the war great advances were made in the design of Diesel-type oil engines and to-day they may be classed as prime movers which have demonstrated their value from both the standpoints of economy and dependability, and it is my opinion that the time has arrived for water-works engineers to give the oil engines serious consideration if they are going to operate their plants at the highest possible economy.

Water-works installations have for many years held the record for high efficiency, the results obtained in large pumping plants being far and above any performance that could be hoped for in plants developing power for industry, the nature of pumping service being such as to render this high efficiency possible. Surprising as it may seem an oil engine-driven unit consisting of a Diesel oil engine geared to a horizontal plunger pump, of the size that we are considering, can give a duty far greater than the

largest and most refined type of steam-driven pumping unit that has ever been built. For instance let us take the duty ordinarily obtained on a cross-compound pumping engine of 3 000 000-gal. capacity; this is as mentioned previously 124 000 000 ft. lb. per 1 000 lb. of steam. An oil-engine-driven unit of this same size can operate on a cost for oil that would be equivalent to a duty of at least 225 000 000 ft. lb. per 1 000 lb. of steam.

In the case of the steam engine the economy of a plant will vary greatly in accordance with its size. With the oil engine, however, the

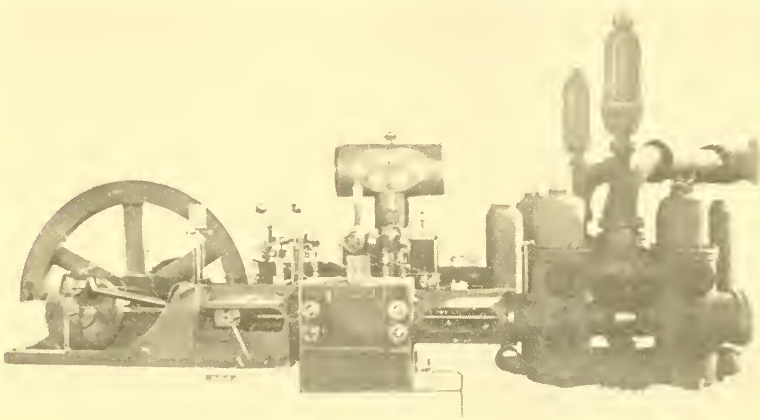

FIG. 1. CRANK AND FLY-WHEEL PUMPING ENGINE.

efficiency of comparatively small units is almost as good as the units of very large size, and this feature is making it a very attractive proposition for water-works pumping installations of small and medium sizes.

To familiarize our minds with the various types of pumping units we are discussing, a few illustrations will no doubt be of assistance.

FIGURE 1.

This illustration shows a pumping engine of 3 000 000-gal. capacity and is no doubt familiar to you all as it is very universally used in modern high-grade pumping service. This unit is provided with Corliss valve gear and is of the type and size of a unit recently installed by the Webster Water Works of Webster, Mass., and is the unit from which we obtained the costs and performance included in the tabulation to be shown later and which you may remember we have mentioned as 124 000 000 ft. lb. per 1 000 lb. of steam.

Figure 2.

This shows the turbine-driven centrifugal pump in use at the High Service Pumping Station of the Brookline Water Works. This particular unit is of 1 000 000-gal. capacity and you can judge of the amount of space taken by the size of windows and other fittings in the engine room. The

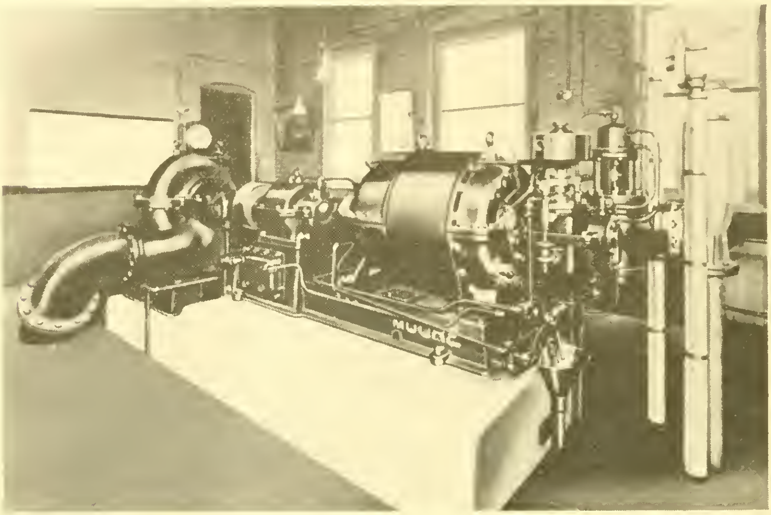

Fig. 2. Turbine Driven Centrifugal Pump.

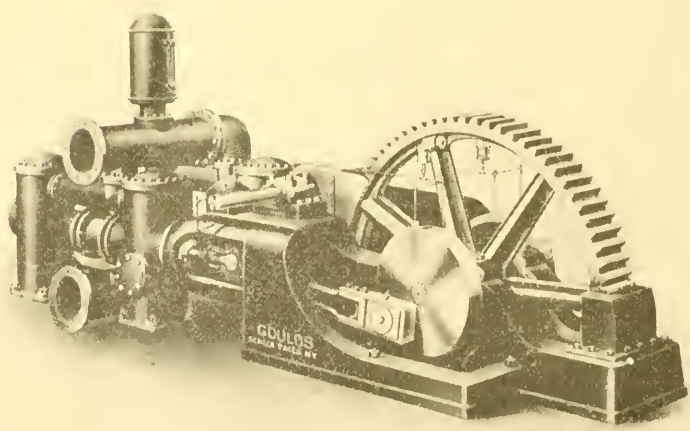

Fig. 3. Horizontal Plunger Pump for Motor Drive.

condenser and air pump are located in the basement adjacent to the foundation. The speed of the pump is about 1 600 r.p.m., and this is accommodated to the turbine speed of approximately 4 500 r.p.m. by means of the Herringbone reduction gears interposed between the two. A unit of this size and type is capable of delivering from 95 000 000 to 100 000 000 ft. lb. of energy, per 1 000 lb. of steam under average conditions found in existing plants.

Figure 3.

This figure shows a horizontal plunger pump, the pump end itself being practically the same as the crank and fly-wheel steam-driven pump illustrated in the first figure. This pump, however, is provided with a large gear for operation by means of an electric motor. In smaller sizes the motor-driven geared pump is usually of the vertical triplex pump.

Figure 4.

Here we have the direct-connected centrifugal pump. This has the lowest first cost and requires a smaller space than any type of pump that

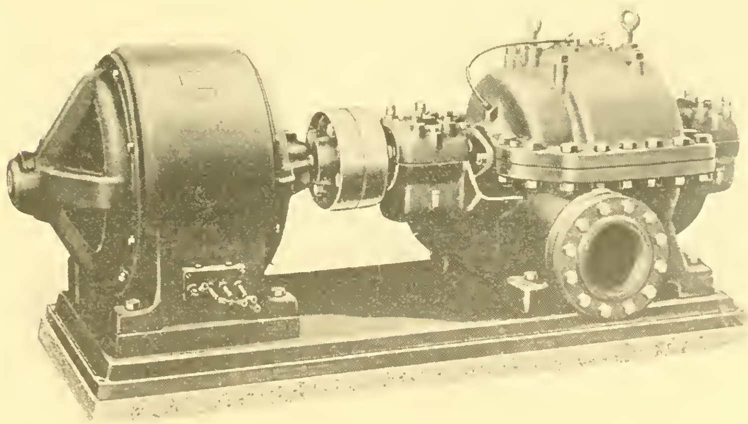

Fig. 4. Motor Driven Centrifugal Pump.

can be considered for a pumping installation, but it is also the lowest in pumping efficiency. In many cases, however, the low first cost and small amount of attendance required may justify its use where electric current can be obtained at a very low price.

In considering the installation of electrically-driven apparatus it is very important to consider the possibility of interruption of service. Some

of you will doubtless remember the interruptions due to the sleet storm about two years ago, and wherever there is a possibility of an interruption of this nature it is advisable to provide an additional drive for the electrically-driven pump with either an oil or gasoline engine. In the case of the centrifugal pump this is very easily accomplished as the shaft can be provided with a coupling at each end, one coupling to be connected to the motor and the other to the oil or gasoline engine. When operating on the motor the coupling bolts are removed from the engine coupling which remains idle.

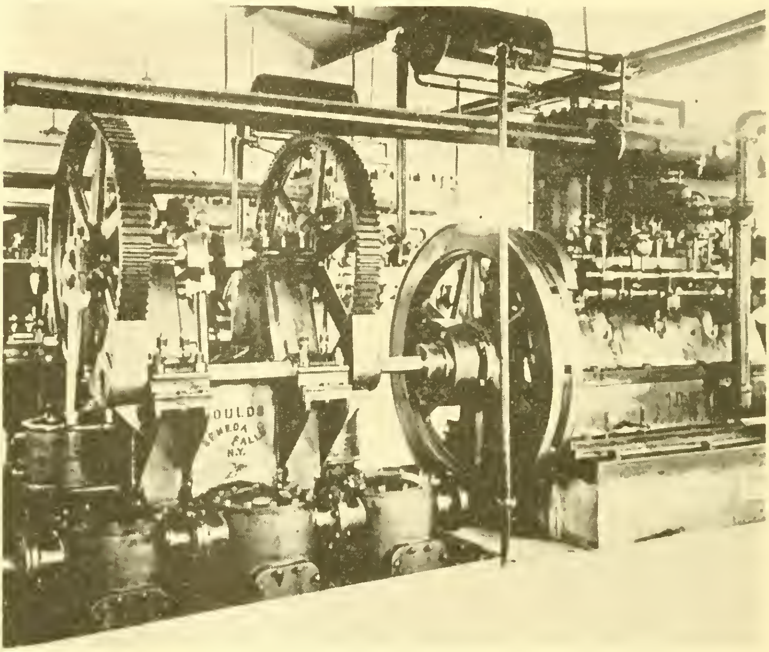

Fig. 5. Vertical Triplex Pump Driven by Oil Engine.

Figure 5.

We now come to the oil-engine-driven units. This illustration shows a triplex pump of a capacity considerably smaller than what we are considering in this paper but of interest as a type.

Figure 6.

This shows another type of oil-engine drive for a geared pump, this being about the same capacity as the previous figure. The engine in this case is a single-cylinder Diesel.

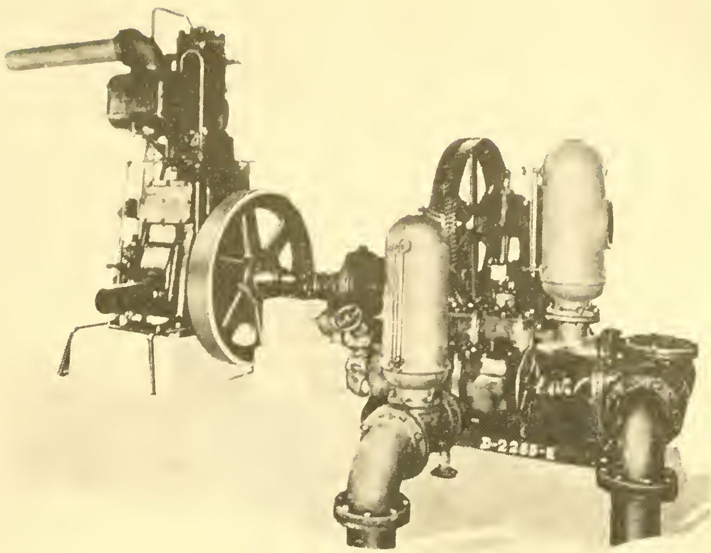

Fig. 6. Vertical Triplex Pump Driven by Single Cylinder Diesel Type Oil Engine.

Figure 7.

This next and last illustration of pumping equipment shows a horizontal plunger pump of about 3 000 000-gal. capacity geared to a 2-cylinder Diesel engine. This particular unit was installed in the water works of New Britain, Conn., about a year ago, and in the tabulation of comparative

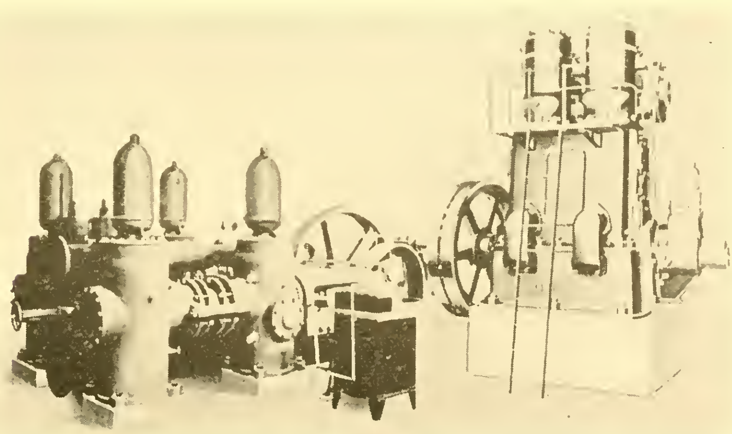

Fig. 7. Horizontal Plunger Pump Driven by Two Cylinder Diesel Type Oil Engine.

costs which I have referred to several times I have used the cost and performance data of this installation. The amount of space taken up is probably slightly in excess of a steam-driven unit of the same size.

In the March meeting of the Water Works Association Dr. Charles E. Lucke read a paper on oil-engine performance supplemented by a paper read by H. M. Chase based on the performance of either this or a similar unit.

COMPARISON OF OPERATION COSTS OF VARIOUS TYPES OF PUMPING EQUIPMENT.
CAPACITY 3 MILLION GALLONS IN 24 HOURS.
INSTALLED AS ADDITION TO EXISTING STEAM PLANT.

	Steam Driven.		Electrically Driven.		Oil Engine Driven.
	Crank and Fly-Wheel Plunger Pump.	Turbine-Driven Centriufgal Pump.	Horizontal Plunger Pump.	Centrifugal Pump.	Horizontal Plunger Pump.
Cost of unit installed with appurtenances and necessary change to building..	$33 000	$15 000	$17 500	$10 000	$31 000
On Basis of Pumping Eight Hours Per Day.					
Interest and depreciation..	$3 960	$2 250	$2 530	$1 500	$4 650
Cost of fuel or current.....	2 660	3 480	6 170	6 870	1 450
Cost of banking fires for 16 hours..................	820	820	.....	.....	.....
Cost of coal for heating...	.....	.....	200	200	100
	$7 440	$6 550	$8 900	$8 570	$6 200
On Basis of Pumping Sixteen Hours Per Day.					
Interest and depreciation..	$3 960	$2 250	$2 530	$1 500	$4 650
Cost of fuel or current....	5 330	6 950	11 010	12 100	2 900
Cost of banking fires for 8 hours..................	410	410	.....	.....	.....
Cost of coal for heating...	.....	.....	200	200	100
	$9 700	$9 610	$13 740	$13 800	$7 650
On Basis of Pumping Twenty-Four Hours Per Day.					
Interest and depreciation..	$3 960	$2 250	$2 530	$1 500	$4 650
Cost of fuel or current....	7 990	10 400	15 700	17 250	4 350
Cost of banking fires......	.....	.....	.....	.....	.....
Cost of coal for heating..	.....	.....	200	200	.....
	$11 950	$12 650	$18 430	$18 950	$9 000

In order to select the pumping equipment for any particular installation there are many things to be considered and several angles from which

the proposition may be viewed, and in the tabulation here shown I have eliminated all items of operating cost that would be practically the same no matter what type of unit might be installed.

As a multiplicity of figures will sometimes obscure the salient points and dwarf their importance, in this tabulation I have taken only the fixed charges consisting of interest and depreciation and the cost of fuel or current. The interest and depreciation on the crank and fly-wheel pumping engine I have taken at 12 per cent., whereas on all of the other types this has been taken at 15 per cent. The cost of coal I have taken at $8.50 per ton. The cost of current I have based on the charges as made by the Boston Edison Company for the current consumption required for an installation of this size, and this figures out as listed below:

2.00 cents per k.w.h. on the basis of an eight-hour day.
1.70 cents on the basis of a sixteen-hour day.
1.64 cents on the basis of a twenty-four-hour pumping day.

In some localities adjacent to a large water power, current may be obtained at somewhat lower rates, but I think that on the whole, current will cost more rather than less than the figures here given. In figuring the steam consumption and the oil consumption I have based the calculations on the guarantees as made by the manufacturers.

I wish to repeat here that we are considering only an installation as an addition to an existing plant. An entirely new installation would be a different matter and while the principles involved would be the same I have not tried to cover the question of a new installation in this paper.

One of the important factors in considering a problem of this kind is the number of hours a day the plant is to be operated. With a large reservoir capacity eight hours pumping will usually suffice. With an ample standpipe and a small demand at night many stations operate with two shifts totalling sixteen or eighteen hours. Other plants pumping against direct pressure have to operate a full twenty-four-hour day.

Now let us consider the first case in this tabulation, a plant operated eight hours per day running at the rate of 3 mil. gal. in twenty-four hours, or 2 088 gal. a minute. The first column shows a crank and fly-wheel pumping engine with interest and depreciation, fuel for pumping and fuel for banking fires sixteen hours per day, making a total of these three items of $7 440 per year. The next in line is the turbine-driven pump with a total of $6 550 per year. The electrically-operated units figure $8 900 yearly cost for the plunger type against $8 570 for the centrifugal. The oil engine shows the lowest yearly cost, this being $6 200. On the basis of the eight-hour day any one of these types could be selected with good reason. Referring to the steam drive, while the turbine-driven pump shows a lower operating cost, the Water Board might decide that with the money available in their treasury they would be justified in purchasing

the highest grade equipment with an assured long life at high efficiency. If on the other hand it would be necessary for them to borrow money to finance the larger expenditure they would undoubtedly purchase the steam turbine-driven outfit. With the operating costs shown for either of the electrical units they would scarcely be justified in installing either of these unless their boiler plant happened to be in such poor condition that the entire replacement of this part of the station would be required in a short time. There is very little choice between the plunger pump and the centrifugal pump from the standpoint of operating costs, and the probability is that with the lower investment and the lower operating costs the centrifugal pump would be selected instead of the higher-priced plunger pump, if electric drive should be decided upon.

The oil engine shows a yearly operating cost of $6 200 as against $6 550 for the turbine-driven centrifugal, and with the steam plant in good condition and the operating force thoroughly trained in handling steam machinery it would not seem advisable to change to oil for the slight difference in operating cost shown.

The next tabulation or the sixteen-hour day shows quite a change in conditions. The fixed charges remain the same but the cost of fuel brings the most efficient apparatus strongly forward. With the slight difference between the crank and fly-wheel pumping engine and the turbine-driven centrifugal pump there is no doubt that the crank and fly-wheel would be chosen as the greater value on account of the lower fuel consumption, and the probability that this type of pump would still be in service twenty or more years after installation, if its capacity should be sufficient for the increased demand, and as the growth of the community is always considered in determining the size of unit, a selection would undoubtedly be made of sufficient capacity for quite a number of years in advance.

On the sixteen-hour day the two types of electrical unit are again of about equal operating cost, but these costs are so far above steam operation as to put them out of the running unless current can be obtained at an extremely low price.

In the sixteen-hour day the oil engine shows to much greater advantage and a saving of $2 000 per year in operating costs is something that cannot be ignored. There is always a resistance against making a radical change, and unless a good reason can be found for change it is undoubtedly wise to tread the known and beaten path in a matter as important as the water supply for a community. However, the path of dependability has already been beaten in marine service where oil-engine-operated vessels make long voyages without a single shut down of their engines. They have amply proven their merit.

The twenty-four-hour day shows a still greater advantage for the crank and fly-wheel pumping engine in a steam-operated plant and clearly demonstrates the inadvisability of purchased electric power for operating

under these conditions. The oil engine shows very close to $3 000 difference in operating cost and from the standpoint of station economy is clearly the best choice in this latter comparison.

In gathering the data and making up this tabulation I have tried as far as possible to use figures that I knew to be correct both as to installation costs and operating expenses. The crank and fly-wheel pumping engine, the turbine-driven pump and the electrically-driven centrifugal pump are based on the costs of installations actually put in. Similar installations made in other plants would probably vary somewhat from the figures given, and all of these costs therefore are to be taken as approximate. The chief value of a tabulation of this kind is to bring out the salient points and emphasize the extreme care with which the problem should be approached. Each and every installation is a problem by itself, and unless viewed from every angle, and every factor carefully weighed it is very easy to make a selection that will be disappointing in the results obtained. Before making a selection it is always advisable to have the problem thoroughly analyzed by an engineer versed in all the phases of the situation.

Mistakes in engineering are usually costly and it is only by careful diagnosis that these may be avoided and satisfactory results assured.

Discussion.

Mr. Caleb M. Saville.* I would like to ask Mr. Mazzur if the same relative differences that he has shown in his tabulations, which I understand were for a three-million-gallon plant, would hold for one of less capacity and one of greater capacity, that is, in a general way.

Mr. Mazzur. In a general way, yes. There would be a change, especially in the electrical. As the consumption of current goes down the rate goes up. You will notice that for the 8-hr. day it was 2 cents per k.w.h.; for the 16-hr. day, 1.7; for the 24-hr. day, 1.64. Up to 20 k.w.h. the Boston Edison Company has a flat charge of $2 for the service; then a certain number of k.w.h. — I think it is 1 000 or 2 000 — at 3 cents; then another space for 2 cents, all of which will amount to 10 000 k.w.h.; and after that it is at the flat rate of 1 cent. So that if you use a large amount of current you get the benefit of the 1 cent rate above 10 000 k.w.h. per month. The smaller the unit the more it will cost per k.w.h.

Mr. Saville. My question was a little more as to the efficiency of the engines themselves.

Mr. Mazzur. They will go down somewhat. In the case of the oil engine, they will not go down so very much.

Mr. Saville. Would they go down in the same relative proportions, each to the others; or in the smaller capacity would one of the plants be more efficient than the other?

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

Mr. Mazzur. I think in the small plant you would find that the economy would go down in steam-driven units faster than it would in electrically-driven units. In the oil engine it would be very nearly flat; there would not be very much change. The oil engine goes down very slowly. In other words, the oil engine in the smaller capacity is very nearly as efficient as in the larger sizes.

Mr. J. M. Diven.* Wouldn't the 10-mil. or 20-mil. direct-acting steam engine show better economy than the small one? In other words, wouldn't you get up to something like 200 mil. ft. lb.?

Mr. Mazzur. In the large steam engines you get over 200, to perhaps 210 — I know they have reached 203 and 205, as against 124 mil. in the small size. That would be going into triple expansion engines.

Mr. Francis T. Kemble.† Around Boston do they make any difference in regard to the charge for certain hours of electric current? Do they require them to be off the line while the peak is on? And the peak load is generally around six o'clock in the evening. Do they penalize them?

Mr. Mazzur. I do not know of that.

Mr. Kemble. That makes some difference in electrical operation.

Mr. Mazzur. If they do make a change, I do not know it. It might be in a special contract. But the rates as published and given out for prospective purchasers of current, as I have seen them, do not take that in.

Mr. Henry A. Symonds.‡ I want to express my appreciation of the splendid paper that we have listened to. Mr. Mazzur has brought out most clearly the special features of the comparison between the different types of drive for moderate-size pumping plants.

The question of steam, oil or electricity comes up in practically every installation. Unless a very careful study is made of the merits of the different cases, the electric drive is apt to have a decided advantage because it takes up small space, it has a low first cost, it apparently can be operated without much supervision, it comes the nearest to being foolproof of any type which can be installed, it requires for ordinary operation no highly experienced man; but a more careful study of the cases frequently shows up certain defects in the first reasoning.

For instance, if you compare the oil engine with the electric drive on the basis of no attendance for the electric drive and full attendance with a high-class man for the oil engine, you make a very favorable case for the electric drive. But here again the practical working out is not according to the theory that is advanced. You will find that more or less attendance is given the electric drive; in fact, in most plants of a size to take care of a moderate-size water works it is thought best to keep some one there at all times while the machine is operating. There are exceptions to that, but that is the common rule. In fact, the actual cost of attendance usually

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* Secretary, American Water Works Association.

† Secretary, New Rochelle, N. Y., Water Company.

‡ Consulting Engineer, Boston, Mass.

does run very nearly the same on the electrically-driven plant as it does on the oil-driven. That may not be as it should be; in fact, I do not think it is. I believe we should operate more with non-attendance than we are doing.

Regarding operating costs, I can't add anything to what Mr. Mazzur has said. There is such a difference between the cost of any ordinary operation by electricity and that of oil that, while the attractive features of the electric drive — the low first cost, small space required for the pumping station, and ease of operation — appeal very strongly, if a careful study is made, it is evident in nine cases out of ten that the oil engine is ahead in economy.

In an installation which has been made within the last month, there was a strong prejudice in favor of using one oil-engine drive for the principal work and a stand-by with electric drive, and the design was completed with that in view, but we found in that particular locality the current was uncertain. Some of the mills were out of power at times when they were depending on electricity, and prejudice existed against having to depend at any time on electric power with this defect, so the plant was redesigned and two oil engines installed.

Now, of course, as the first cost of the oil engine is much greater than the motor, depreciation and interest become much greater items. The close comparison by Mr. Mazzur between the different types of pumps brought out that particular feature. There is a marked difference in the efficiency between the centrifugal pump and the vertical triplex, but in some of the cases the difference was actually more than lost because of depreciation and interest.

I should say here that one important thing is to have, in operating an oil engine, a fairly competent man. In different plants that have come to my attention, some of which have been under my direction for a time, it appeared that the life of those engines was just about in proportion to the capacity of the men operating them. There are some engines that we have run for fifteen years under skillful, competent, economical men that seem to be as good as the day when they were put in. Others that we have not run as long have largely gone to pieces because of the less efficient maintenance. Depreciation does cut a great figure, and becomes much greater with the oil engines.

But the fact is that in analyzing every feature that enters into the determination of what power shall be used, you can install the present Diesel or semi-Diesel — I should say the semi-Diesel is more suited to the smaller plants in some cases than the true Diesel, although there has been a wonderful advance in getting out the true Diesel at a moderate price — allow the heavier depreciation and interest charges, and full attendance, as against the lower depreciation, lower interest charge and eliminate entirely the attendance on the electrical units, and in the average case the oil engine will still come out decidedly ahead.

Mr. J. M. Diven. The speaker fully agrees with the last speaker on the nonattendance question. No machinery can be trusted to entirely take care of itself. Some years ago the speaker had an experience with an electric-driven triplex pump, pumping from a well. The pump was located about two miles from the power house and the only attention it had was by a man who went there once a day to oil and examine the outfit. Pumping was at intervals to a reservoir. One day after the power had been turned on it was found that no water was being pumped and a trip to the pump house revealed a mass of scrap iron, a completely ruined pump. Just what happened was never found out, whether the sudden start caused the motor and pump to race or whether the pump failed to take suction owing to low water in the well will never be known.

Mr. Kemble. I should like to ask as regards the oil engine, when you try to run at capacity for any length of time, how it stands up. In steam units you run 75 to 80 per cent., and if forced to run at full capacity for any extended time at all you find your runner making all sorts of noises. Have you had anything of that kind?

Mr. Mazzur. I do not believe I am as competent to answer that question as Mr. Hatch of New Britain. If Mr. Hatch is here, I think he can tell us.

Mr. W. L. Hatch.* I think this installation was completed in the spring, and after the completion it was run at capacity, 3 mil. a day for thirty days, with only one shut-down, which was only for a few minutes, during that time. The card indicator showed that it was running up to 3 mil. I think the contract figure was approximately 2 900 000. It ran over that: between 2 900 000 and 3 000 000 all of that time. Since that time it has been in operation eight hours out of twenty-four at the rate of 3 mil. gal., and is still running, and we have had absolutely no trouble, no shut-down for any engine trouble during the summer. The actual cost figures are approximately one cent per 100 cu. ft. of water pumped, against about a 360-ft. head. The first figures showed slightly under the rating, and after the pump had been running for two or three weeks it went over the rating, so that it is running now at slightly over the rated amount.

Mr. F. H. Hayes.† It has given me great pleasure to listen to the paper of Mr. Mazzur.

Possibly I might say something about the dependability of oil engines. At Scituate some years ago there were two oil engines put in, and on a hill there was a standpipe. It became a question of when to start the engine and not overflow the standpipe. They experimented in this way. They fixed a tank on the wall and put oil in it. By observing the height of the water in the standpipe they were able to determine the quantity of oil necessary to be supplied to the engine in order to fill the standpipe. When the tank was emptied the engine stopped. An attendant went there only at night and morning. That, I think, was twenty years ago.

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* Chairman, Board of Water Commissioners, New Britain, Conn.

† Of Hayes Pump and Machinery Company, Boston, Mass.

I am glad to hear what Mr. Mazzur has said in regard to the oil engine, for the reason that I have tried to interest so many in it.

The real point of why you should put in an oil engine instead of a steam engine or steam turbine is because of the low cost of operation. There is no other way of pumping water for so little money as by the use of oil engines. These are, as we all know, semi-Diesel engines. There have been great improvements in the semi-Diesel engine. I personally have used most all of the oil engines. I have used the Hornsby-Akroyd, the Otto, Fairbanks-Morse, Crescent, Meitz & Weiss, and now we are using some of the Bessemer engines.

But when you get into the matter of the upkeep of oil engines, I think that Mr. Mazzur has gone a little far in saying it is 15 per cent., if I correctly understood him, when he compares the oil engine.

Mr. Mazzur. That is what I figured.

Mr. Hayes. From our experience with them, we do not get any repairs for them, except once in a while. Once in a while there is a bad one that comes out from the shop, but you can't help that. But when you come to compare them all the way through their upkeep is less even than the steam engine, and I am very glad to know that they are coming to the front.

Mr. Frank A. Marston.* Answering a question, I know of one instance in which a problem was taken up with the Edison Electric Illuminating Company of Boston and they indicated a willingness, on a unit perhaps of such size as we have been talking about this afternoon, to make a favorable special rate in case the pump was run during certain hours, as I remember it, in the early morning. I know of other large electric companies in this vicinity who have submitted similar offers to make special rates not covered by their schedules, where the pumping would be done at a time that would be of benefit to them.

Another thought has come to me in connection with stand-by service, which was furnished in connection with an inquiry made in the city of Springfield this year. The power company indicated a willingness to put electric motors in a pumping station without subjecting the user to a stand-by charge provided there was no other form of power in the station, but if electric motors were to be put in in addition to a Diesel engine or a steam engine, in other words, be a stand-by source of power, then a servic charge would be levied which would involve prohibitive expense.

I would like to mention a hypothetical case and ask Mr. Mazzur's judgment as to the effect on the efficiency of the prime movers. Assume you had a 3-mil.-gal. pumping unit, but operating at a rate of 800 000 gal. per day on the average and with a maximum rate of 3 mil. gal. per day for fire service. What would be the relative efficiencies of the several types of prime movers referred to?

* Of Metcalf & Eddy, Boston, Mass.

Mr. Mazzur. The oil engine would not be as good under those conditions for horse power delivered. To work it out on a question of fixed charges and operating costs would be rather difficult now for mental arithmetic. But I can say that under a varying load the steam engine will come nearer its guaranteed economy than the oil engine will — probably much nearer on a wide range of variation.

Mr. Marston. Where would the steam turbine come? I assume that the electrical equipment would not be economical under those conditions.

Mr. Mazzur. The steam turbine would not be as good as the crank and fly-wheel engine. It can be regulated, but of course we know that when you cut down on the speed of a turbine you commence to lose in efficiency very rapidly.

Mr. Hayes. We have had occasion to answer some questions in reference to the use of oil as compared with electricity, and for your information I will say that it has worked out this way: taking oil at 10 cents a gal., you will have to obtain your electric power for less than a half a cent per k.w.h. We have proved that a great many times.

Mr. A. Prescott Folwell.* I saw about a week or two ago some figures sent out by the Federal Government that were compiled up to within a few weeks, I think, showing figures for the past four years for plants generating electricity. Of course this is not exactly water works, but along that same line. The power generated by electric plants during the four years — 1919 to 1923 inclusive — had increased 12 per cent. in the case of those using coal and 52 per cent. for those using oil, showing a much more rapid increase in the use of oil than in coal during the last four years.

Mr. E. P. Howard.† Our company builds, of course, all of the various types of machinery which have been talked about here tonight. In regard to this question of repairs and maintenance, and things of that kind, while Mr. Mazzur did not directly mention it, I think that he included the figure for repairs and maintenance in his depreciation on each one of the units, so that it was taken care of.

Now, he also probably — at least I think he did — took it at what he thought was a fair average. We do know that there are plants of all of these various types that run for years and years and nothing happens; we do know, also, that perhaps in some other places something does happen. We do know that perhaps in a plant that has run for several years without anything happening, they may have a breakdown which will amount to quite a considerable item in any one element. So that the only fair way to get at it is to take a fair average over the entire field, which I think Mr. Mazzur has done. And I want to say here that I do not think I have ever heard a fairer explanation and comparison of the different types than he has made here to-night.

* Editor, *Public Works.*

† Of Worthington Pump and Machinery Corporation.

In regard to the different types of engines on a variable load, we have a number of cases here in New England where there is a system with a standpipe in it and perhaps a limited storage in the standpipe. Perhaps you have not got enough water in your standpipe to carry you through a heavy fire. Perhaps you have not got enough to carry you through 24 hr. without pumping. There you have to start up in the morning and pump at a fixed rate until the standpipe is full, and then perhaps slow down for the remainder of the day and operate at reduced capacity until you get ready to shut down at night and leave a sufficient amount of water in the standpipe to carry you through until the next day. Now, for those variable conditions we have found that there is nothing that quite equals the crank and fly-wheel machine over that variation, because it keeps nearer to its maximum efficiency. The oil engine can be made to pretty nearly approach that, because it can have its speed varied without any very great change in its economy. But it does change somewhat. But probably next to the fly-wheel engine it keeps the closest to its maximum efficiency.

I do not know that there is anything in particular that I have to say more, except, on the electric end in a great many cases, there are some things that come up after you have got the electric power in, that make your bills larger than you thought they were going to be before you started in, unless you are fortunate enough to make a contract similar to what the president did in his case, where he limited the electric company to a fixed sum, which should not be exceeded, for pumping a certain amount of water.

Mr. Charles W. Sherman.* In a comparison between the 8-hr., 16-hr. and 24-hr.-per-day operation, Mr. Mazzur has used the same figure for fixed charges covering interest and depreciation, and, as Mr. Howard seems to understand it, of ordinary repairs. It seems to me that a plant that is run 24 hr. a day will necessarily have to meet more costs for repairs in the term of its life than one running 8 hr. a day, and there is an item there that will have some effect. It may be too slight to have any bearing on this question.

Mr. Mazzur. I think that the figure I took for interest, depreciation and ordinary repairs was large enough to cover the 24-hr. service. I think the general consensus of opinion here is that I have been too high on those figures.

Mr. Sherman. It would be less than that on an 8-hr. service?

Mr. Mazzur. Yes, it would.

President Sanders. There is one feature of comparison of costs of running a 3-mil.-gal. pump by steam and then changing to electricity, that I am not sure has been considered in your paper. With steam you would have to have an engineer and a fireman while with electricity only one man would be required. That would make some difference in the

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comparison between steam and electricity figuring on an 8-hr. day. Were your figures made on that basis, Mr. Mazzur?

Mr. Mazzur. I believe I mentioned in the paper that both of the 3-mil.-gal. plants had one man on duty for each shift. I do not think that many plants of greater capacity than 3 mil. get along with one man, but I do know of several plants of that capacity where just one man does the firing, the wheeling of the coal and the oiling of the engine. In other words, it is a one-man plant. And if it is a 16-hr. day, then two are employed — that is, one man per shift. If it is a 24-hr. day, three men, or one man at a time. And in a way I selected that particular limit of size as being one on which you could make the compairson without figuring labor at all.

Mr. Kemble. As regards the having but one man on the plant I might call to your attention that this is a matter that has been given pretty thorough consideration and that, in many instances, operating men have decided that they did not want theirs to be a one-man plant. A single man may have a spasm or something happen to him. Again a single man may wander away from his plant and leave it to take care of itself.

Of course on a small plant, the runner and the fireman may have but little to do and have much time on their hands.

Mr. Mazzur. The plant I mentioned in the paper, in which I used the crank and fly-wheel pumping engine, is the Webster Water Works, and with the crank and fly-wheel pumping engine they are using about 1 000 or 1 100 lb. of coal a day, and that is not a very big day's shovelling for a man. Previous to that they were using a duplex pump and he was shovelling just about twice the amount of coal, and he still looked healthy. So that I do not believe that they intend to add to the force now. I think there are more plants of that size running with one man than there are with two on duty.

Mr. Howard. If I might add one more word, which I forgot, in regard to the cost of the oil-engine fuel. One gentleman spoke about the cost of fuel having gone up so much in the past few years. These costs which were put on the sheets by Mr. Mazzur were on the basis of present-day cost of oil, and if oil only cost half or two thirds as much a few years ago you see how the comparison was then. Even at the present cost of oil you have seen how the comparison is. Of course those costs are also based on the latest up-to-date Diesel engine, which has a higher first cost, more money invested, but which has a lower average consumption to offset it.

THE COVERING OF OPEN SERVICE RESERVOIRS IN WHICH FILTERED OR GROUND WATERS ARE STORED.

BY GEORGE C. BUNKER* AND AUGUST G. NOLTE.†

[Read September 19, 1923.]

In the past many open service reservoirs have been constructed due to one of the following reasons:

(1) To a lack of knowledge of the changes which will take place in stored ground or filtered waters;

(2) To the necessity of building and placing in service a storage basin of any kind in the shortest possible time in order to effect an improvement in the sanitary conditions of a community suffering from the lack of a water supply;

(3) To the use of the reservoirs for storing unfiltered water until they were required later on for the storage of filtered water.

In recent years a diminishing number of open service reservoirs for the storage of ground and filtered waters have been built as the public has become more interested in the protection of its water supplies and in many instances has reached the conclusion that if it is necessary to purify the latter it is fully as necessary to keep them in the same condition of purity prior to consumption. However, a few open service reservoirs are still constructed through reasons of false economy, through the blindness of amateur engineers to certain well known facts concerning the storage of water, or through their failure to include a roof as an integral part of a reservoir instead of submitting two estimates of cost, one with a roof and the other without a roof. The latter procedure is certain to start an argument by one or more of the parties to whom the proposition goes for approval because a chance is presented to reduce the first cost of the reservoir and thereby effect an apparent saving. This leads to the necessity of demonstrating that the present apparent saving will develop into a future expenditure of the same amount with about 50 per cent. more added to it to pay for an experiment which has been tried many times without success in other communities.

In general the covering of an open service reservoir, once built, is harder to accomplish than it is to obtain the additional money for the cover before the construction of the reservoir is started, assuming of course that filtered or ground water is to be stored in it. We know of no better illustration of the difficulty of covering an existing open service reservoir

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than the struggles of Edward E. Wall, Water Commissioner of St. Louis, Mo., to obtain an appropriation for covering the open service reservoirs at Baden and Bissell's Point, the latter of which were built about 1870 as sedimentation basins. Attention is called to the following illuminating remarks from his annual report for 1920:[1]

"As an example of how needed improvements that could and should have been done at least five years ago, will now cost almost twice as much, the covering of the filtered water storage basins at Baden and Bissell's Point may be cited.

"Every year beginning with 1915 an ordinance has been drawn appropriating money for this work; every year the Board of Public Service has approved the proposition and recommended the bill to the Board of Aldermen for passage; with equal regularity, each year, the bill is never allowed to reach the stage where it can be voted upon.

"This work was not postponed from year to year because of the lack of available funds, but because laymen have opposed their judgment against that of trained and experienced engineers, and decided that the basins did not need covering.

"It has been said that politics is the only profession in which the amateur presumes to enter the lists on equal terms with the professional, but here we have a case where those who can not qualify even as amateurs, pass upon a highly technical question with more of assurance than is assumed by the expert.

"As pointed out in the Chemist's report, page 58, the Bissell's Point basins exposed the filtered water to contamination from the dirt and filth blowing from the stock trains passing over the Merchants Bridge, and from the flying refuse of the public dump just south of Ferry Street.

"That they should have been left uncovered so long is a reproach against the City's regard for cleanliness, but a continuation of this indifference will constitute more than a reproach, it will become a positive disgrace."

Unfortunately politicians do not have a monopoly in passing judgment upon "a highly technical question" for not infrequently amateur, inexperienced, or narrow-minded engineers are offenders in this respect with the result that more attention is paid to their opinions, backed up by their profession or by their position, simply because they are occupying positions of greater authority, than to those of men ranking as experts in the purification of water. Then again some engineers with minds too narrow to take into consideration the broader aspects of the subject will not consider any question of this sort except from the standpoint of dollars and cents.

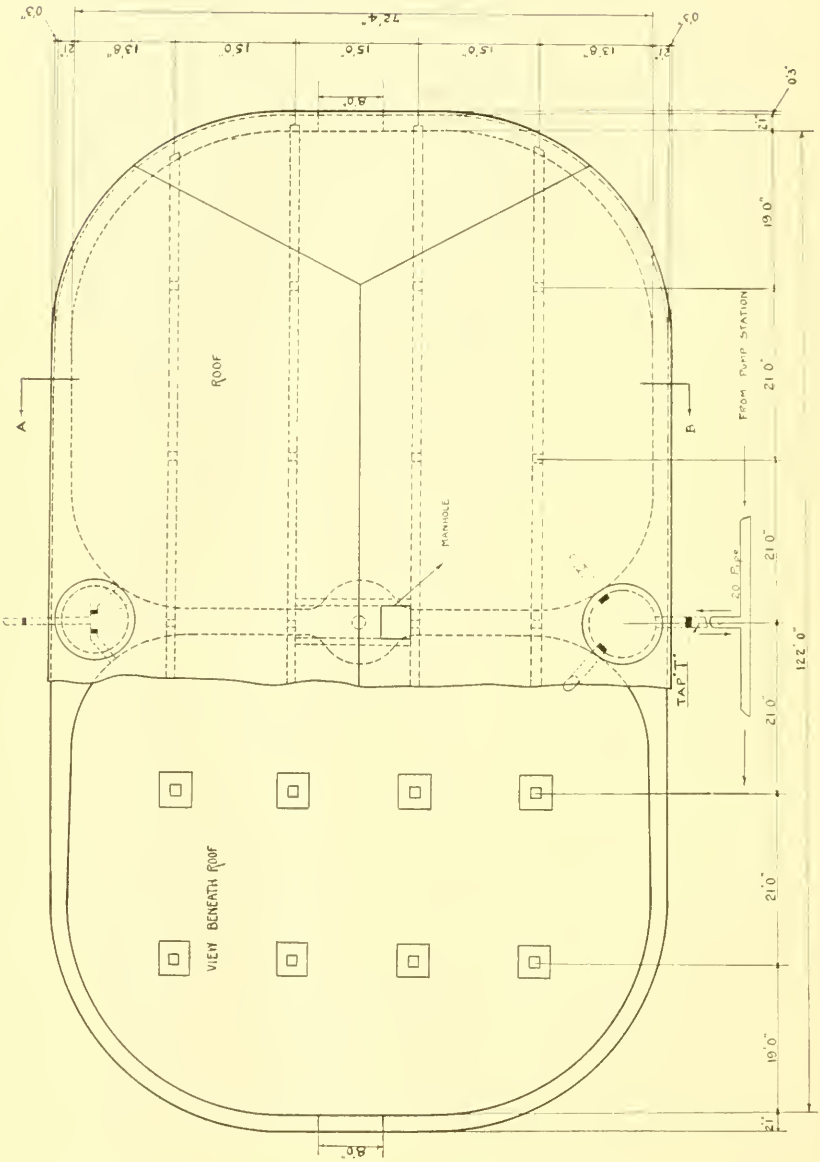
The conditions leading up to the covering of a low-service reservoir on the Canal Zone and the resulting improvement may be of some assistance to those who are working to obtain covers for reservoirs or to those who contemplate the construction of new reservoirs. The water supply for the Pacific end of the Canal Zone is obtained from the Chagres River, the largest stream discharging into Gatun Lake. From the intake it is pumped through 11 miles of cast-iron pipe to the Miraflores Purification Plant where it is aërated, clarified with aluminum sulphate, filtered, and disinfected.

After disinfection with liquid chlorine the greater part of the water flows by gravity for a distance of four miles to a pumping station at Balboa. In this station there are two high-service and three low-service pumps so

Fig. 1 — Bird's-eye View of City of Panama from Ancon Hill, 1855.

Fig. 2. — High Service Reservoir Constructed in 1909.

Fig. 3. — High Service Reservoir with Addition and Roof Constructed in 1911.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A
B

PLAN

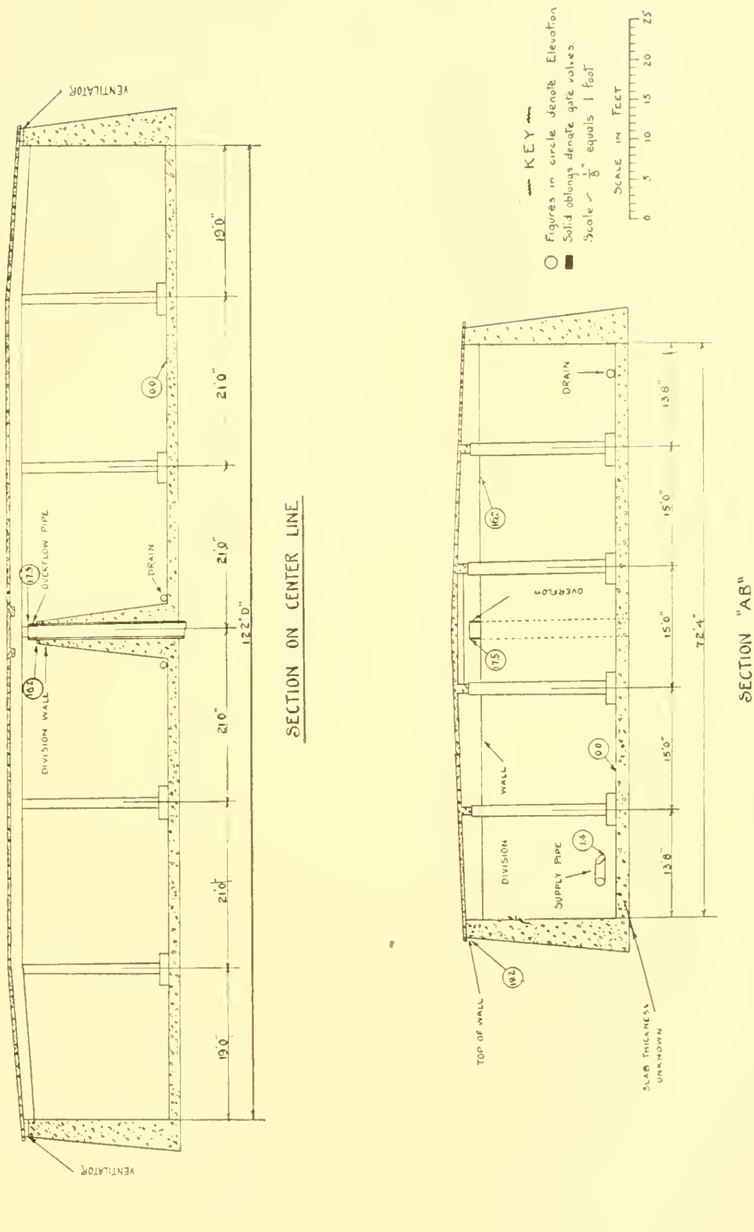

FIG. 4.—DETAILS OF LOW SERVICE RESERVOIR.

interconnected that any one of the five may be used for pumping water into any part of the distribution system. Connected to the distribution system there are two concrete reservoirs or surge tanks; one, the high-service reservoir, the other, the low-service reservoir.

During the fiscal year ended June 30, 1909, an uncovered, reinforced concrete high-service reservoir,[2] 120 by 125 ft. in plan by 13 ft. deep, with a capacity of 1 000 000 gal., was built on the side of Ancon Hill at a point such that the elevation of the floor was 283.5 ft. above sea level. Its cost was $32 573. Prior to this time an elevated tank, 50 000 gal. capacity, furnished water to the Ancon Hospital grounds but increased consumption rendered it inadequate for the service demanded of it. On June 1, 1914, a reinforced concrete addition[3] to this reservoir was completed and placed in service, increasing the storage capacity by 1 500 000 gal., thus making the total capacity 2 500 000 gal. The addition was built in an irregular shape on account of the topography and in plan measured 110 ft. in width and from 127 ft. to 186 ft. 5 in. in length. At the same time a roof was placed over the combined reservoirs. From this reservoir filtered and disinfected water is now supplied to those sections lying at greater elevations than can be served from the low service reservoir.

The low-service reservoir[4] was placed in service November 1, 1905, as part of the system of water works installed by the Americans to improve the sanitary conditions in the city of Panama. In connection with the construction of this reservoir the following comment by Davis[5] is of interest:

> "Its construction was delayed in favor of more important matters until the dry season of 1905 came on; and during that season every drop of water in the vicinity was needed for Ancon Hospital and none was available for concrete."

The reservoir was set on top of a knoll on one side of the Canal Zone community known as Ancon, the elevation of the floor being 119.1 ft. above sea level, sufficiently high for supplying the city of Panama and the lower parts of Ancon and Balboa with a normal water pressure of 35 lbs. per sq. in. It is oval in shape, 122 ft. long by 72 ft. 4 in. wide, inside measurements, by 19 ft. 2 in. deep. It was constructed of concrete and the lower half of the structure was backed up by earth. A division wall, 16 ft. $2\frac{1}{2}$ in. high, along its short axis, divides the reservoir into two sections of equal size. At one end of the division wall there is a well into which the water discharges from the pipe line from the pump station, and from which it may be diverted into either section through a short length of pipe, 20 in. in diameter, the flow line of which is 16 in. above the floor. When water is flowing out from the reservoir it passes from each section through the same pipes into this well and thence into the distribution system.

In the center of the reservoir, running down through the division wall, there is a 16-in. overflow pipe, the top of which sets at such an elevation as to give a maximum depth of 17 ft. $6\frac{1}{2}$ in. of water or a capacity of 500 000

gal. in each section. At the other end of the division wall there is another well serving as a valve box for the valves on the 6-in. waste pipes which connect to a single drain pipe.

From October, 1913, up to the completion of the Miraflores Purification Plant in March, 1915, the low-service reservoir was supplied with water from Miraflores Lake filtered through pressure filters in Ancon. The supply taken from this lake contained, off and on, large numbers of diatoms. From time to time the filter runs would be shortened to such an extent by these diatoms that sufficient water could not be filtered to keep the reservoirs full and to furnish sufficient wash water. Relief for short periods was obtained by applying copper sulphate to the arm of Miraflores Lake from which the supply was taken. As a result considerable numbers of diatoms were present in the filtered water delivered into the reservoir so that in 10 samples of this water collected between September 3, 1914 and January 21, 1915, the total organisms varied from 11 to 390 and the amorphous matter from 10 to 400 standard units per c.c. After the filtered water from the Miraflores Plant was discharged into the reservoir the organisms decreased gradually in numbers so that during November and December, 1915, the examinations yielded counts not exceeding 14 standard units per c.c. Up to October, 1918, routine microscopic examinations were made of samples of water from both the low-service (uncovered) and the high-service (covered) reservoirs. At that time, due to pressure of other work and changes made necessary by the War, these examinations were stopped and have never been resumed as a matter of routine work. The following table gives a comparison of the numbers of organisms in the two reservoirs:

TABLE NO. 1.

Microscopic Organisms in Samples of Water from the Low and High Service Reservoirs in Ancon, C. Z.

Total Organisms in Standard Units Per C.C., 1 500 C.C. of Water Concentrated.

Year.	Low-Service Reservoir, Uncovered.					High-Service Reservoir, Covered.				
	Maximum.	Minimum.	No. of Samples examined	Samples containing no organisms.		Maximum.	Minimum.	No. of Samples examined	Samples containing no organisms.	
				No.	Per cent.				No.	Per cent.
1916	124	0	61	21	34	21	0	53	25	47
1917	24	0	75	68	91	4	0	46	39	85
1918	39	0	40	20	50	3	0	40	38	95

From this table it is seen that the largest number of organisms were found in the uncovered reservoir and that a larger percentage of the samples from the covered reservoir were free from organisms, *i.e.*, none were found in the concentrates from 1 500 c.c. of water, which of course does not mean that there were none in the entire body of water.

During several years daily samples of water have been collected from taps in buildings in Ancon and in the city of Panama in order to determine if the proper amount of liquid chlorine was being added to the filtered water leaving the Purification Plant. During the fiscal years ended June 30, 1918, 1919, and 1920 the colonies of bacteria averaged less than 50 per c.c.,* the actual figures as published in the annual reports being as follows:

Year Ended June 30.	Colonies of Bacteria Per c.c. 24 Hours at 37.5° C.	B. Coli Index Per Liter.
1918†	24.1	23.0
1919	46.4	12.1
1920	15.4	7.9

Occasionally a count greater than 100 per c.c. was obtained from one of the taps but in some cases it was found that water was dripping over the outside of the faucet, thereby contaminating the sample, and in other cases it was considered that the collector of the sample had contaminated it as the counts from the same tap on previous days had been running low and no change had been made in the application of the chlorine. Furthermore the counts from the samples collected on the same day from other taps on the distribution system were low which was considered as confirming the theory that the sample yielding the high count had been contaminated. All of the sampling points were located on service pipes tapped into mains through which there was a constant circulation of water so that the influence of dead ends was eliminated. Later on we came to the conclusion that the sporadic high counts were due to other causes than contamination by the collector as we will point out in another part of this paper.

Starting in June, 1920, several high counts of over 100 bacteria per c.c. were obtained from taps on the distribution system supplied by the low-service reservoir and members of the Colon group were isolated from 14 out of 300 portions, 10 c.c. each, of 60 samples of water. Hitherto members of the Colon group had not been isolated from more than 5 out of 300 portions, 10 c.c. each, of 60 samples of water. In July, members of the Colon group were isolated from 21 out of 285 portions, 10 c.c. each, of 57 samples of water. In August there was about the same percentage isolation of members of the Colon group but a greater number of samples contained more than 100 bacteria per c.c., while in September and October several samples of water from the same taps yielded counts of 200 to 1 200 bacteria per c.c.

Table No. 2 shows the bacteriological characteristics of samples of water collected from the distribution system during five months prior to the covering of the reservoir.

* All counts of bacteria given in this paper were determined on nutrient agar after 24 hours incubation at 37.5° C.

† First year during which liquid chlorine was used in place of hypochlorite of lime.

TABLE NO. 2.

SUMMARY OF THE BACTERIOLOGICAL CHARACTERISTICS OF THE SAMPLES OF WATER COLLECTED FROM TAPS ON THE DISTRIBUTION SYSTEM DURING THE MONTHS OF JUNE TO OCTOBER, INCLUSIVE, 1920.

Month.	Colonies of Bacteria Per C.C. on Nutrient Agar. 24 Hours at 37.5° C.				Members of the Colon Group.			
	No. of Samples.	Average.	Maximum.	Per Cent. of Samples Yielding Sterile Plates.	No. of Samples.	10 C.C. Portions.*		
						No. Tested.	No. Negative.	Per Cent. Negative.
1920								
June	59	22	150	6.8	60	300	286	95.3
July	57	36	170	8.8	57	285	264	92.6
August	61	59	275	1.6	61	305	287	94.1
September	60	85	800	6.7	60	300	295	98.3
October	93	70	1 200	10.7	62	310	307	99.0

TABLE NO. 3.

SUMMARY OF THE BACTERIOLOGICAL CHARACTERISTICS OF THE SAMPLES OF WATER COLLECTED FROM TAPS ON THE DISTRIBUTION SYSTEM DURING THE MONTHS OF NOVEMBER 1921 TO MARCH, 1922, INCLUSIVE.

Month.	Colonies of Bacteria per C.C. on Nutrient Agar. 24 Hours at 37.5° C.				Members of the Colon Group.			
	No. of Samples.	Average.	Maximum.	Per Cent. of Samples Yielding Sterile Plates.	No. of Samples.	10 C.C. Portions.*		
						No. Tested.	No. Negative.	Per Cent. Negative.
1921								
November	65	6	65	20.0	39	195	195	100.0
December	77	4	43	22.1	46	230	230	100.0
1922								
January	69	1	7	42.0	38	190	190	100.0
February	69	5	55	23.2	53	265	265	100.0
March	67	9	55	13.4	67	332	329	99.1

The puzzling part of the problem was that on one day a high count was obtained from one sample and low counts from the other samples; on another day the counts from all the samples were high; while on the preceding or following day the counts were low again. A special set of samples, was collected from various points on the distribution system in order to eliminate the factor of carelessness in the routine collection of the samples, with the result that the bacterial content of the samples varied sufficiently to indicate that some other explanation would have to be sought besides contamination during collection. In order to eliminate any influences of dirty mains or dead ends a request was made for a

* Five 10 C.C. portions of each sample are inoculated into lactose broth.

general flushing of the mains in the district supplied by the low-service reservoir. This was carried out on September 8, 1920, but high counts in some of the samples still continued intermittently. On September 13 the north half of the reservoir was cleaned and on the following day the south half was cleaned. On September 14 the counts from all the samples collected were low but at the end of four days the counts were again high. On the same days samples collected from the district supplied by the covered high-service reservoir yielded low counts.

For several days we had been convinced that conditions in the low-service reservoir itself were responsible for the high counts in the distribution system, in other words that the large numbers of bacteria found in the mains were actually present in the water before it left the reservoir. However, we were thrown off the track for a time by obtaining low counts in samples from a tap "T" (see Fig. 4) on the one main through which the water entered and left the reservoir. On studying the conditions we found that this reservoir was virtually an open standpipe with one main leading into it. When the pumpage into the distribution system exceeded the consumption, the excess water flowed into the reservoir and the level was raised. With the reverse condition existing water flowed from the reservoir into the distribution system and the level dropped. With these conditions in mind samples were collected from tap "T" at intervals of thirty minutes over a period of six hours. The counts from these samples showed that the water entering the reservoir contained only two or three colonies of bacteria per c.c. while that flowing out contained from 205 to 420 colonies per c.c.

To make certain that the water pumped into the reservoir from the Balboa pump station contained low numbers of bacteria, *i.e.*, that no multiplication occurred in the disinfected water during its flow through four miles of pipe line from the purification plant, samples were collected at the Balboa pump station over a period of six hours at intervals of thirty minutes. The colonies of bacteria ranged from 0 to 3 per c.c. These results showed conclusively that the water pumped into the reservoir from the pump station, through a 20-in. pipe line, 4 950 ft. long, contained small numbers of bacteria.

On the day following the above tests a sample of water, collected from a tap in a building close to the reservoir, while the level of the water in the latter was falling, contained 380 bacteria per c.c. A few hours later a sample collected from the same tap but with the water flowing into the reservoir contained only 5 bacteria per c.c. All of these tests indicated definitely that when the pumpage into the reservoir exceeded the consumption in the district, the mains, at least those in the close vicinity of the reservoir were filled with water containing small numbers of bacteria. On the other hand when the consumption exceeded the pumpage for several hours, the mains were filled with water from the reservoir which contained several hundred bacteria. In other words a multiplication of bacteria

was taking place in the reservoir. The daily samples in Ancon and the city of Panama were collected between 7.00 and 8.00 A.M. Between these hours the level of the water in the low-service reservoir was usually falling and consequently samples collected between these hours and within a reasonable distance from the reservoir contained larger numbers of bacteria than at some other period during the day when the water was rising in the reservoir.

During the period of August to November, 1920, chlorine was applied to the filtered water leaving the purification plant at the rate of 3.23 to 3.63 lbs. per million gal. (monthly averages) or 0.39 to 0.44 part per million of available chlorine. The majority of the samples collected from the distribution system supplied from this reservoir during this period contained no residual chlorine while the remainder contained not over 0.01 part per million. However if we had tried to stop the multiplication of bacteria by carrying an excess of residual chlorine, the consumers would have complained about the odor and taste of the water supply.

On September 27 both sections of the reservoir were again emptied, cleaned, and refilled with water from the Balboa pump station. On September 28 the counts had fallen but by October 1 they had increased again and varied from 1 300 colonies per c.c., in samples from the surface, to 1 800 colonies per c.c., in samples from the bottom.

On October 6 one side of the reservoir was emptied and the surface of the walls examined. The entire surface of the unplastered walls was badly pitted or roughened, the depressions in some places being as much as one half inch deep. All of the depressions contained a dark greenish deposit which under the microscope showed the presence of diatoms, filaments of algæ, bacteria, and amorphous matter.

In order to ascertain to what extent this deposit might contribute to the multiplication of bacteria in the water in the reservoir the following experiment was performed. Two sterile wide mouth bottles, of about 1 liter capacity, were each filled with 750 c.c. of disinfected filtered water from the main running to the Balboa pump station. Plates made from each bottle of water showed no colonies on nutrient agar after 24 hours incubation at 37.5° C. One bottle was marked " A " and the other, " B." To the water in " B " there was added 0.1542 gram of the deposit described above. To the water in " A " nothing was added.

Bottle " B " was thoroughly shaken for two minutes and a plate was then made from the water in it. At the end of 24 hours only 4 colonies of bacteria per c.c. had developed. Immediately after the above samples had been taken, both bottles, uncovered, were set outdoors. At the end of 24 hours exposure the bottles were thoroughly shaken and plates made from the water in each. Bottle " A " was found to contain 4 colonies of bacteria per c.c. while bottle " B " contained 700 colonies per c.c. Both bottles were again set outdoors for another 24 hours, at the end of which time the water in each bottle was again examined. The water in bottle

"A" contained 5 colonies of bacteria per c.c., while that in bottle "B" contained 165 000 colonies per c.c. Bottle "A" was again set outdoors for five more days, at the end of which time it was found to contain only 7 colonies of bacteria per c.c.

This experiment demonstrated:

First. That the bacteria (developing on nutrient agar at 37.5° C.) in the disinfected filtered water do not multiply when it is placed outdoors in a sterile bottle for periods of one, two, and seven days.

Second. That the deposit on the walls of the reservoir was the principal factor in the multiplication of the bacteria in the water stored in it.

It is true that the water in the reservoir was continually changing while that in bottle "B" was not changed during the experiment. However, the water in the reservoir was never completely displaced by fresh water from the pump station, the elevation in general varying each day from about 10 to 17 ft. 6 in. The 16 inches of water on the bottom below the effluent pipe would never be entirely changed under the operating conditions.

In the latter part of October, 1920, both sections of the reservoir were emptied, the walls cleaned as thoroughly as possible, and a coat of whitewash applied although we insisted that the application of the latter was useless for preventing a recurrence of the multiplication of the bacteria. During the latter part of this month the recommendation was made that the unplastered portions of the interior surface of the reservoir be plastered and that a roof be placed over it.

After the reservoir had been cleaned and whitewashed the multiplication of bacteria still continued although not to the same extent because the cleaning with wire brushes had removed a large part of the deposit from the walls. On November 10 the south section of the reservoir, filled to an elevation of 16 ft. 4 in., was treated with $9\frac{3}{4}$ lb. of copper sulphate, equivalent to a dosage of about 2.3 parts per million, and was taken out of service. On the 15th and 16th the treated water was run to waste and the walls and bottom flushed with filtered and disinfected water. On the 17th the north section was taken out of service, treated in a similar manner, and then replaced in service on the 22nd.

During the first half of January, 1921, the unplastered portions of the walls, amounting to 637 sq. yds., were plastered in order to prevent the accumulation of algæ and food material to the extent made possible by the existing rough surfaces. This step proved to be of material assistance in reducing the degree of multiplication of the bacteria in the stored water and was advisable in view of the uncertainty of covering the reservoir at a later date. The plastering, including all preparatory work, cost $1 678.95.

With a few exceptions the counts from the samples collected from the taps on the distribution system ran below 50 colonies per c.c. during the months of December, 1920, and January and February, 1921, and

no members of the Colon group were found in 1, 10, and 50 c.c. portions of the 136 samples collected.

Near the end of the latter month a vigorous growth of green filamentous algæ appeared in the reservoir. Later on the predominant organism was identified by Professor Geo. T. Moore * as Mougeotia. From this time on we experienced continuous trouble with this organism, the growth developing to such an extent that two weeks after a cleaning of the reservoir the water would contain many long strings and floating masses,

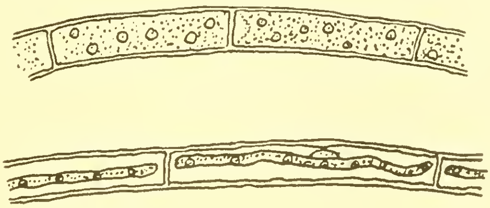

FIG. 5. — MOUGEOTIA SPECIMEN.

A. Showing the Surface of the Chlorophyll Plate. B. Showing the Edge of the Chlorophyll Plate. X About 500. (Original.) After Ward & Whipple.

necessitating repeated cleanings at intervals of three weeks or less. Masses of the growth entered the pipes of the distribution system and decomposed with the result that disagreeable odors and tastes were imparted to the water drawn from the taps in some of the houses. The progressive development of the growth of the Mougeotia after a cleaning of the reservoir was watched by collecting samples of water from each half of the reservoir and filtering a quart portion through a cotton disc furnished with the Wizard Sediment Tester.† Attention was called to this simple apparatus by Professor George C. Whipple[6] in 1914 and superintendents of water works will find it very useful for detecting growths of microscopic organisms in uncovered reservoirs. We also made frequent inspections of the reservoir to watch the development of the Mougeotia.

During the period of trouble with this organism the bacteria in the samples from the distribution system did not exceed 50 per c.c. in contrast with the high counts obtained from similar samples prior to the cleaning and plastering of the walls of the reservoir. It is evident that the cleanings of the reservoir were made frequently enough to prevent the death of the Mougeotia and an accompanying increase in bacteria. It is also evident that the frequent cleanings of the reservoir prevented the passage into the distribution system of any great amount of the Mougeotia with subsequent decomposition and an accompanying increase in bacteria. Undoubtedly if samples of water had been collected from a great many points on the distribution system some of the samples would have yielded high counts due to the Mougeotia being carried into sections of slow circulation

* Director, Missouri Botanical Garden, St. Louis, Mo.

† Creamery Package Manufacturing Company, Albany, N. Y.

and light draft with subsequent settling out on the bottom of the mains and decomposition. If the reservoir had been allowed to remain uncovered for several years longer we have no doubt that the bacterial counts would have risen because there would have been a cumulative deposition of algæ in the mains and through their decomposition a cumulative increase of food material for the bacteria.

We did not consider it advisable to treat the water with copper sulphate and keep the reservoir in service and objections were made to taking it out of service entirely so that the contents might be treated with copper sulphate and allowed to stand for a few days in order to make certain that all of the cells adhering to the walls would be killed. It was useless to treat one section at a time with copper sulphate, waste the water after standing a few days, and refill it with fresh water, because this water would have been seeded from the growth in the other section, as birds were continually skimming through the surface of the water in both sections.

Later on the funds for covering the reservoir became available and the roof over the north section, — the south section remaining in service, — was completed on August 21, 1921. The north section was then placed in service and the roof over the south section completed on October 25, 1921.

In constructing the roof over each section, eight reinforced concrete columns, 14 in. square, spaced as shown in Figure 4, were poured in place on top of concrete footings, 4 ft. square and 1 ft. thick. The supporting beams, 12 by 18 in., for the 4½-in.-reinforced-concrete slab, were poured first, followed by the slab itself before the concrete had set hard. No expansion joints were used in the roof slab, the fresh concrete of each day's work being run up against that of the previous day's work. Later on these joints or cracks were chipped out and asphalt was poured in to prevent drippings into the reservoir during rains. Run of bank gravel from the Chagres river, passed through a 2-in. mesh screen, was used in the proportion of 8 cu. ft. to 1¼ bags of Portland cement. Over the division wall the roof is supported by four short columns resting on the wall. In the center of the roof a manhole, 4 ft. square, was left and covered with a ventilated shelter. The roof was given a pitch of ½ in. per ft. and the top was given a float finish. Screened ventilators were left in the wall under the roof on either end of the reservoir. The area of the roof is 8 967 sq. ft. The covering of the reservoir was done by the Municipal Engineering Division under the direction of the Municipal Engineer, George W. Green, at a total cost of $12 823.74.

Before each section was placed in service it was cleaned by a gang and then filled with filtered water to which 20 lb. of copper sulphate were added, equivalent to about 4.5 parts per million. After standing for about 36 hr. the water was run to waste and the walls and bottom of the section flushed with filtered and disinfected water, after which it was refilled and placed in service.

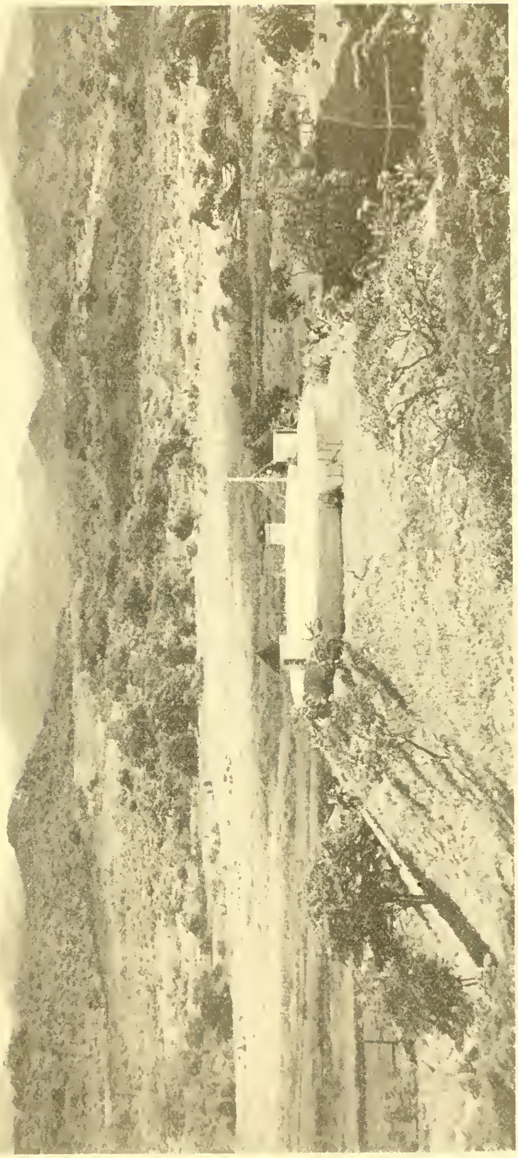

FIG. 6. — LOW SERVICE RESERVOIR AFTER CONSTRUCTION OF ROOF IN 1921.

After the roof over each section was completed and the reservoir as a whole was thrown into service no trouble was experienced from the multiplication of bacteria or from the development of algæ in the stored water.

Table No. 3 shows the bacteriological characteristics of samples of water collected from the distribution system during the first five months after the completion of the roof. If this table be compared with Table No. 2 the improvement effected by covering the reservoir is clearly evident. Other samples of water collected from the water standing in the reservoir yielded counts which correspond closely with those from samples collected from the high-service reservoir.

The improvements effected by the covering of this reservoir may be summarized as follows:

1. The maintenance of the filtered and disinfected water in the same condition in which it leaves the purification plant by:

a. Preventing the entrance of dust, bird droppings, leaves and other foreign matter.

b. Preventing the growth of algæ.

2. The elimination of frequent cleanings of the reservoir which means that the maximum storage capacity of the system is always available in case of a shutdown of the purification plant.

3. The lessening of the danger of the pollution of the reservoir by the gang engaged in cleaning it or by trespassers.

4. The water will enter the distribution system at a lower temperature.

When the senior author took charge of the purification of the water supplies in 1914 he anticipated that the multiplication of algæ in this reservoir, in view of the favorable temperature conditions, would be a continuous source of trouble but, as shown above, it was not until 1921 that vigorous growths of Mougeotia suddenly appeared and developed into a nuisance, not only to the consumers but to the maintenance force as well, on account of the frequent cleanings. If this reservoir had not been seeded with Mougeotia, probably by birds, it might have run on for several years without any trouble developing from multiplication of algæ with the exception that the deposits on the walls would cause an increase in the bacterial content of the water. The frequent daily changing of the water in the reservoir, the scarcity of organisms in the filtered water entering the reservoir, and their exposure for a few minutes to the dose of chlorine added to the water leaving the purification plant, were undoubtedly important factors in restraining the multiplication of the organisms entering the reservoir. On the other hand there is no reason, except that of luck, why the reservoir was not seeded at an earlier date, either by birds or by the wind, with some organism which like Mougeotia would have found an ideal environment.

In Kingston, Jamaica, the effluent from the slow sand filters is stored in uncovered basins and a luxuriant growth of algæ was seen by one of us

(G. C. Bunker) during a visit to the two filter plants. Detached pieces of the growth work their way into the service pipes of the consumers and cause complaints. In Cartago, Costa Rica, there are two uncovered reservoirs in which spring water is stored which are cleaned each week on account of the rapid multiplication of algæ and the collection of dirt which blows into the water from the surrounding streets. The mean air temperature averages 63° F.

Fig. 7. — Open Reservoir in San Jose, Costa Rica, 1921.

San Jose, the capital of Costa Rica, is also supplied with spring water which is carefully protected against light and exposure to dust until it reaches the city where it is discharged into an old reservoir, consisting of five uncovered tanks. The spring water is stored in three of the tanks while polluted river water for irrigation purposes is stored in the other two tanks. All connections between the two sets of tanks have been removed. The tanks in which the spring water is stored are cleaned each week on account of vigorous growths of algæ. In this case one of us (G. C. Bunker) agreed with the Municipal Engineer that it would be best leave the reservoir uncovered because later on some one in power might take advantage of a roof to increase the supply of water by making a connection with the tanks in which the river water is stored while if the reservoir remains uncovered such a connection may be easily detected. Eventually the river water will have to be stored in a separate reservoir which will allow the use of the entire reservoir for the spring water and thus permit the construction of a roof. The two other reservoirs in the water-supply system, used for the collection of the water from the springs are well built and covered.

At least the conclusion may be safely drawn that while an uncovered reservoir in the Tropics may be used for some time, several years perhaps, for storing filtered water without affecting its quality, it is certain, sooner or later, that a multiplication of algæ with accompanying troubles will occur. It is useless to make a prediction as to how soon a multiplication

of algæ will start in a new uncovered reservoir in which filtered or ground water is stored, with the idea that a roof may be placed over it later on in order to reduce the initial cost.

On account of the disgraceful situation which the Board of Aldermen of St. Louis, Mo., has allowed to develop through their misdirected opposition to the covering of the open basins for the storage of filtered water, thereby bringing an unenviable notoriety to an otherwise first-class water supply and arousing suspicions as to its potability among visitors to the city, we feel that it is advisable to bring out certain facts at some length in order to increase the value of our paper to those who may be contending with a similar problem in smaller communities. One of us (A. G. Nolte) while at the Chain of Rocks filter plant (St. Louis, Mo.) originated and conducted a series of observations to determine the extent of bacterial pollution of the water in these open basins as a result of dust falling on the surface. The following description of the work as well as Table No. 4 were taken from a report published in 1916.[7]

"During September and October analyses of the air at the basins at Baden and Bissell's Point were made. These analyses were made to determine the extent of bacterial pollution of the water in the basins caused by the deposition of dust particles containing bacteria on the surface of the water.

"Baden basin is located close to Broadway, and although a brick wall is placed between it and the street, there is a great deal of dust and dirt carried over onto the surface of the water. This is especially true in dry weather when traffic is heavy. The only analysis made at Baden was made on a damp day when traffic was light, due to the fact that it was a holiday.

"The basins at Bissell's Point adjoin the west approach of the Merchants Bridge on the south and the Burlington tracks on the east. Either of these lend to the pollution of the clear water in these basins under certain conditions. A strong wind from the south at a time when a long train of cattle cars is passing over the approach contributes materially to the pollution of the basins. At the time of the analysis on the 13th of September, under conditions shown in the table, there were in addition to large numbers of bacteria, soot and dust, many hundreds of chips of wood, some several inches in length, blown into basin No. 1.

"In order to preserve the high quality of the water now leaving the filter plant, it will be necessary to cover the basins at Baden and Bissell's Point. This will be necessary not only to prevent pollution by the air-borne bacteria, but also by surface drainage, by the eggs or larvæ of Chironomus and by the possibility of algae growths.

"The method of analysis was as follows: Wooden trays containing six solidified agar plates were floated on the surface of the water when calm or held a few inches above the surface when choppy. The positions of the trays during the various tests are shown in the table. The plates, each 6.92 sq. in. in area, were exposed for various intervals of time, then covered and incubated at 37° C. for twenty-four hrs. before being counted. The results are expressed in number of organisms deposited per square foot of surface per minute.

"In addition to the agar plates, plates of Endo's medium were exposed. Though some growth took place, no colon colonies were found."

TABLE NO. 4.

BACTERIAL AIR ANALYSES AT BADEN AND BISSELL'S POINT RESERVOIRS.

Date of Collection. 1915.	Location of		Weather Conditions.		Local Air Disturbances During Exposure.	Organisms Deposited, Number per Sq. Ft. Reservoir Surface per Min.	
	Reservoir.	Trays of Plates.	Before Exposure.	During Exposure.		37° C. Organisms.	B. Coli.
Sept. 6.	Baden.	North, east and south corners, West wall. Center of basin.	Cloudy. Foggy. Rain.	Warm, sunshine. Slight wind from south-east.	None apparent.	45	0
Sept. 13	Bissell's Point.	3 at intervals along south wall. 2 at intervals along north wall.	Dry, sunshine. Strong wind from south.	As before exposure.	Three trains, totalling 50 cars, passing over Merchants Bridge approach. Wood and soot blowing into basin.	315	0
Sept. 21	Bissell's Point.	3 at intervals along south wall. 2 at intervals along north wall.	Cool, dark. Considerable wind from south.	As before exposure.	Two trains of passenger cars, totalling 16 coaches, passed over approach. Considerable cinders blown into basin.	75	0
Sept. 29	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Cool, dark. Slight wind from east.	As before exposure.	Four trains, totalling about 60 box cars and passenger coaches passed over approach.	40	0
Oct. 5	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Dark, cool. Moderate wind from north.	As before exposure.	One train passed over Burlington tracks.	69	0
Oct. 14	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Warm, cloudy. Moderate wind from north.	As before exposure.	One train (double header), totalling 40 box and coal cars, passed over approach.	55	0
Oct. 20	Bissell's Point.	3 at intervals along east wall. 2 at intervals along west wall.	Warm. Considerable wind from northwest.	As before exposure.	One train, composed of 40 box and coal cars, passed over approach.	57	0
Oct. 27	Bissell's Point.	3 at intervals along south wall. 2 in southeast corner of basin.	Warm. Slight wind from south-east.	As before exposure.	None apparent.	125	0

Table No. 4 shows that the number of organisms deposited per minute per square foot of the surface area of the reservoir varied from 45 to 315 per c.c.

In the annual report for 1920, page 58, August V. Graf, Chief Chemist, wrote as follows concerning these basins:

"In October the three south basins at Bissell's Point were taken out of service and cleaned. The water in these basins contained a great number of crustacea and diatoms. These basins being uncovered and exposed to the offal of trains passing over the Merchants' Bridge approach and to the dirt and dust of the dumps immediately south of the basins, cannot be kept free from objectionable matter."

"The usual and expected trouble from crustacea and algæ growths in the Compton Hill basins has been experienced during the year. These basins being situated as they are, with tops of the walls far above the ground, are practically free from outside contamination. As long as the basins at Bissell's Point are allowed to remain uncovered and thereby remain potential sources of contamination, which contamination is carried to Compton Hill, so long will we be unable to furnish a water during the summer months that will be free from objectionable organic growths. We assume that these organisms are harmless, having been declared so by eminent authorities, still that does not justify or mitigate our offense in compelling the people to consume a water that is objectionable both to sight and taste.

"The south basin at Compton Hill was treated three times with copper sulphate and the north basin four times during the summer of 1919. The organism count, not bacteria, was as high as 3 600 per c. c. and seldom was less than 200. The greatest number of crustacea present in any sample obtained was 10 in 500 c. c. The amount of copper sulphate added varied from 0.3 to 0.6 parts per million. After treatment the basins remained out of service for several days to permit the dead algæ and the copper sulphate to settle."

In his annual report for the year ending April 1, 1922, page 6, Mr. Wall states:

"For the seventh time an ordinance authorizing the covering of the storage basins at Baden and Bissell's Point was approved by the Board of Public Service on September 13, 1921, and forwarded to the Board of Aldermen with the recommendation that it be passed. This time it reached the Board of Estimate and Appointment, but there its progress stopped.

"During the summer of 1921, the water in these basins became so objectionable on account of the organic growths caused by exposure to the sunlight and to contamination from the dust and bacteria carried by the wind, that some of the basins were temporarily taken out of service, and others had to be emptied and cleaned.

"Many people complained of noticing these organisms in the water used in their homes, and assurances that they were harmless did not go very far towards reconciling them to its consumption."

In the same report, page 40, Mr. Cornelius M. Daily, Engineer-in-Charge, Supply and Purifying Section, expressed his opinion of the open basins in the following paragraphs:

"The clear water basins remain uncovered, a source of contamination from various agencies, although the Water Commissioner has introduced bills for appropriating money for this purpose every year since 1916. A comparison of the bacterial count of the water

which leaves the filter plant with the tap water will show a large increase in bacteria of tap water over the filtered water during the summer months which is the result of storage in the open clear water basins.

"We are using various means to keep the water in circulation in these basins which prevents to some extent the multiplication of organisms but are only makeshifts. It is impossible to set an uncovered barrel of water beside a dusty street and keep it pure by stirring. These basins have a combined area of 28.8 acres, which is equivalent to 1.57 sq. ft. for each inhabitant of St. Louis based on a population of 800 000. Who would be willing to have his supply of water in an open barrel whose area is 1.57 sq. ft. for 365 days in the year beside a dirty street? Would he be considered progressive if he left his barrel uncovered?

"The estimated cost of covering Baden basin is $110 000 and the basins Nos. 1 and 2 at Bissell's Point, $182 000."

Again on page 61 of the above mentioned report we find the comments of Mr. Graf on the same subject:

"The high bacterial count on agar, during five months of the year, of the water to mains and to consumers, was due to the fact that the basins at Bissell's Point and Baden being uncovered are subject to contamination especially after heavy rains. Samples of water obtained as the water entered Baden basin showed a count of 45 per c. c. while samples from the basin averaged over 2 000.

"Great numbers of snails were found in the basins during this time and some of them were examined in the laboratory. Five snails were cleaned, washed with sterile distilled water and placed in 500 c. c. of water in a flask. Immediately after placing in a flask, a sample of water was plated and showed a bacterial count of 2. After three hours, the count had increased to 11, and in 20 hours had reached 90 per c. c. In 2½ days the count had increased to 1 500 000. It is possible that the snails had some effect upon the water, helping to increase the number of bacteria."

"Chlorine was added to the water in these basins for several days but the method of adding the chlorine proved so unsatisfactory that it was soon discontinued. If the basins at Baden and Bissell's Point are to remain uncovered, machines for applying chlorine after the water has passed through these basins should be provided."

From Table No. 13, "Comparative Bacteriological Data. 1921-1922," on page 60, we find that the monthly averages of bacteria (developing on nutrient agar at 37° C., 24 hrs. incubation) in the filtered water as it entered the open storage basins, varied from 48 to 55 per c. c. during the months of June to September, inclusive. To this water there was added during the same period, monthly averages of 4.19 to 5.36 lb. of chlorine per million gallons equivalent to 0.50 to 0.64 parts per million of available chlorine. The same water after storage in the basins under discussion and as it was discharged into the mains running to the city, contained from 10 to 2 100 bacteria per c.c. Here we again have a case of bacteria multiplying in filtered and disinfected water while it was standing in uncovered reservoirs, similar to our experience with the low-service reservoir in Ancon, Canal Zone. By the time the above water had reached the consumers in St. Louis a further multiplication had taken place so that the monthly averages of the bacteria in samples collected in the city varied from 7 to 4 100 per c.c.

While mention was made in the 1921 annual report of great increases in bacteria after heavy rains, in the water stored in these uncovered basins, yet Table No. 6, "Comparative Bacteriological Data," showed no such startling figures as those given in the similar Table No. 13, in the 1922 report, so it appears to be reasonable to draw the conclusion that the conditions affecting in a detrimental manner the quality of the filtered and disinfected water stored in the uncovered basins at Baden and Bissell's Point, are rapidly growing worse.

A second application of chlorine to the water drawn from these basins and pumped into the mains leading to the distribution system proper in the city, would undoubtedly reduce the number of bacteria which developed in the basins and possibly prevent further multiplication in the mains, but it would not prevent the growths of algæ, crustacea and other organisms in the basins so that these would continue to pass into the mains and worry the consumer who does not want to see "bugs" in the glass of water he is about to drink.

Of the many covered service reservoirs in use the following are mentioned as examples.

UNITED STATES. — Arkansas: Arkansas City. California: Pasadena. Delaware: Wilmington. District of Columbia: Washington. Illinois: Quincy. Indiana: Indianapolis. Iowa: Dubuque. Louisiana: New Orleans. Maryland: Baltimore. Massachusetts: Brookline, Concord, Springfield, Wellesley. Michigan: Grand Rapids. Minnesota: Minneapolis. New Jersey: New Milford, Perth Amboy. New York: Albany, Ithaca, Watertown, Yonkers. Ohio: Columbus. Pennsylvania: Philadelphia. Virginia: Portsmouth. Wisconsin: Superior.

CANADA, — Montreal; Toronto.

ENGLAND. — Bradford.[8] London: Hampton, Honor Oak, Cross Hill, Burton-on Trent.

FRANCE. — Paris: Menilmontant, Montmartre, Montrouge, Belleville.[9]

PANAMA. — Canal Zone: Ancon.

As examples of the forced covering of service reservoirs, constructed originally without a roof, in order to eliminate troublesome growths of algæ, the following three cases are cited.

1. *Washington, D.C.*[10] In a paper on the covering of one of the reservoirs in this city John Gaub made the following statement concerning the construction of the roof:

"Briefly, the cover was designed as a flat slab concrete floor to carry a live load of 75 lb. per sq. ft. The reservoir is in two compartments, and one of these was covered while the other was in service, thus causing no delay in the use of the water in that section of the city. The slab is 6 in. thick and is supported on 133 columns 16 in. square. The slab is made of a mix consisting of 1 part (Portland) cement, 2 parts sand and 4 parts gravel, and covers 44 600 sq. ft. The cost was about 37 cents per square foot."

2. *Dubuque, Iowa.*[11] An open concrete reservoir, capacity 7 500 000 gal., was built in this city several years ago at a cost of $82 000. Recently a concrete cover was placed over it at an additional expense of

$32 000 because it was necessary to clean the reservoir every ten days in the summer due to algæ growths, which was not only expensive but increased the fire hazard. There is a possibility of the arched top being used as a foundation of a community building or as a skating rink at some future date.

3. *Duluth, Minnesota.*[12] As a result of the investigation of the water supply of Duluth, Minnesota, by the State Board of Health, an open service reservoir is being covered in order to prevent the contamination of the water stored in it.

As examples of the covering of reservoirs at the time of their construction the following six cases are cited.

1. *Arkansas City, Arkansas.*[13] Capacity, 2 000 000 gal.; cost, $52 887.21; shape, circular; dimensions, 156 ft. inside diameter and 14 ft. deep to overflow weir; roof, 5-in.-reinforced-concrete slab with an 8 in.-slope from center to wall; beams, 10 by 15 in. spaced 12 ft. on center each way; columns, 10 by 10 in.; design, ring tension type with walls resting on a subfooting keyed into the rock stratum forming the bottom; the wall is separated from the footing by a specially-designed expansion joint, in order to eliminate cantilever stresses.

"The location of the reservoir being on public park property, it was decided before completion to utilize the top for tennis and volley-ball courts. The manhole openings and ventilators were so placed that ample space was provided for two tennis courts. Pipe couplings or sockets were installed in the roof slab for the net posts, and also sockets around the wall for posts for fencing the entire area."

2. *Perth Amboy, New Jersey.*[14] Capacity, 40 000 000 gal.; cost, $1 095-556; shape, irregular; dimensions, 900 ft. long by 230 to 370 ft. wide and 25 ft. deep; the roof and floor are of flat-slab reinforced-concrete construction, the roof being carried on reinforced-concrete columns; the embankment slopes within the reservoir are lined with plain concrete; the roof slab is covered with earth to a depth of $2\frac{1}{4}$ ft.

3. *Cross Hill Reservoir, London, England.*[15] Capacity, 30 000 000 gal.; cost, £79 000 (1913); shape, hexagonal; dimensions, each hexagonal side has 8 arches with a span of 30 ft. and a radius of 27 ft. $6\frac{1}{2}$ in., and a span and radius of 17 ft. $4\frac{1}{2}$ in. at the angles; the depth is 32 ft.; roof, 217 concrete domes, each 30 ft. in diameter; columns, 16 hexagonal concrete blocks, 18 in. deep and 3 ft. across between parallel sides, for each column or a total of 432.

The claim is made that this reservoir is of unique design and probably the most economical one ever constructed. The cost was about £2 800 per million gal. of storage as compared with an average cost of £5 000 for several small covered service reservoirs built for the London water supply.

4. *Indianapolis, Indiana.*[16] Capacity, 10 000 000 gal.; cost, $223-500, including pipe connections and appurtenances but excluding en-

gineering; shape, rectangular with rounded corners; dimensions, 254 by 542 ft. in plan by 10 ft. $8\frac{1}{2}$ in. deep; roof, slab 9 in. thick designed for total live and dead load of 470 lb. per sq. ft.; 27 in. of filling was placed on the roof; column heads, 6 ft. 6 in. square extending $5\frac{1}{2}$ in. below bottom of roof slab; columns, 24 in. in diameter, spaced on 18 ft. centers, making a total of 420; floor, groined-arch type of construction; circulation, two brick baffle walls insure uniform circulation of water.

The net area of water surface is 136 500 sq. ft. or $3\frac{1}{8}$ acres, and the cost per million gallons stored, exclusive of piping connections, brick baffle walls and engineering, but including all earth work, was $19 150, which is equivalent to $1.415 per sq. ft. of water surface.

5. *Baldwin Reservoir, Cleveland, Ohio.*[17] This reservoir was only recently completed and is referred to by the Engineering News-Record as "perhaps the largest covered reservoir in America." Shape, rectangular; dimensions, 1 035 by 551 ft. in plan by 39 ft. deep; a division wall divides it into two basins of equal size; the floor is of flat-slab plain concrete; the roof is of the groined-arch panel type supported by columns 30 in. in diameter which are strengthened by stiffening walls forming a cross in each basin; special attention was given to the design of the inlets and outlets to ensure a good circulation of water.

6. *Montreal, Quebec, Canada.*[17 1-2]. Capacity, 50 000 000 gal.; shape, rectangular; dimensions, 512 by 525 ft. in plan by 15 ft. 6 in. deep; the roof and floor are of flat-slab reinforced-concrete construction, the former 6 in. thick and the latter 8 in. thick; there are 1 330 reinforced-concrete columns, 16 in. in diameter, spaced 12 ft. 6 in. apart, center to center, both ways; the footings are 5 ft. 8 in. square, of the tapered type, and extend upward above the basin floor a distance of 16 in.

The following four opinions from the writings of authorities on water supplies are quoted to furnish additional proof of the desirability of covering service reservoirs.

1. Fuller and McClintock.[18] "Where a water supply has been filtered and sterilized at considerable expense the best practice demands that it shall not be exposed to possible contamination in open reservoirs.

"In the construction of a new storage reservoir, such as is proposed at Thirty-Third Street and Jackson Avenue, provision should be made for covering the reservoir at the time of its construction."

2. Hazen.[19] "The advantage of storing filtered waters in the dark, where they will keep entirely without deterioration, is so great that it seems certain that the present practice of covering will be continued until the present open reservoirs are all abandoned or covered."

3. Wegmann.[9] "For the storage of ground water, or filtered water, the reservoirs should be covered, as solar light and heat cause growths of vegetation in such waters, such as algæ, which give the water a bad taste.

"Covered service reservoirs are built to protect stored water from (1) solar heat and light, which causes growth of vegetation; (2) from atmospheric impurities; and (3) against malicious pollution."

4. Don and Chisholm.[20] "It is an undeniable if somewhat disconcerting fact that filtered water is very liable to deteriorate if kept for any length of time before being distributed.

"Stored in an open reservoir, water of excellent quality may be invaded by plankton and micro-organisms which would render it unpalatable to the consumer.

"The obvious remedy for algæ and plankton growths is to exclude light by covering the clear-water reservoirs. This plan has been followed at many installations, as at Paris, London, Antwerp, Eltham (for pumped spring water), Nancy, Bedford, etc. Without this precaution it is difficult to maintain the purity of filtered water. Germs drop from the atmosphere or are carried by wind. Thus the reservoir becomes a gathering ground for micro-organisms.

"At most of the principal water works filtered water is stored in covered basins. The largest in the world is that for the Metropolitan supply at Honor Oak. Mr. Bryan, Chief Engineer of the Board, has expressed the opinion that filtered water should not again see the light till it issues from the consumers' taps."

Conclusions.

There is no doubt that the present-day tendency of water-works practice is strongly toward the covering of new service reservoirs, in which either ground or filtered waters are to be stored, at the time they are built, while the old uncovered reservoirs are gradually being covered after the misdirected influence of the amateur water-works men, present in every community, has been overcome by practical demonstrations of what it means to interrupt the water service of a reservoir by frequent cleanings for removing growths of algæ. Six very good reasons may be given for the covering of a service reservoir at the time of its construction, namely:

1. To maintain the water supply in the same condition of purity in which it leaves the purification plant or ground by:

   a. Preventing the entrance of dust, bird droppings, leaves, soot and other foreign matter.

   b. Preventing the growth of algæ.

2. To eliminate frequent cleanings of the reservoir which means that the maximum storage capacity of the system is always available in case of a shutdown of the purification plant or the pump station.

3. To lessen the danger of the pollution of the reservoir by the gang engaged in cleaning it or by trespassers.

4. To prevent loss by evaporation and to maintain the water at a uniform temperature.

5. To effect a saving in the cost of the roof which sooner or later must be constructed because it can be built at a minimum cost and with no interruptions to the water service.

6. Because an uncovered reservoir has no place in a well-designed water-supply system according to the collective expression of engineering judgment.

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Discussion.

Mr. H. N. Blunt.* The character of covering of open reservoirs interests me. We had a similar condition, a small reservoir which, like many others at the time, was not covered. It had a wooden top designed and constructed, and the whole interior whitewashed. I should like very much to hear of any experience where a cover of this type has proved detrimental to the character of the water in a reservoir.

Mr. Caleb M. Saville.† The speaker was rather interested in water-supply conditions at Panama in 1909, and from then on for a few years, and he was interested in the statements in the paper about the seeding of the reservoirs, the sterile water reservoirs, by either the wind or by birds. At that time, when the speaker was there, the supply of drinking water was distilled water. All the water that was supplied to the people for drinking purposes was distilled. It was very noticeable that the first water that was drawn from the stills to be sent out, and which had come in contact with the air, showed a very large number of colonies of bacteria, due, as the author of the paper states, to being seeded from the air.

President Sanders. I think it would be rather interesting to know how the temperature of the waters in those tropical countries runs.

Mr. J. M. Diven.‡ I think the temperature of those waters runs somewhere about 70° to 80° in the reservoirs, if I remember right.

Mr. Robert Spurr Weston.§ I remember water with a temperature as high as 85° down there. I do not think the maximums are very much higher than some of our surface waters get here in the summer. But the average, of course, is very much higher. I know when we take a shower bath down there with the water at 85°, we think it is cold. The temperatures do get down to 60° on some of the surface waters. I should say, as a guess, from 60° to 85°.

Mr. Charles W. Sherman.¶ The presentation of this paper may perhaps cause a little consideration, on the part of those of us who live near Boston and who are interested in the Boston Metropolitan supply, as to what we may perhaps be confronted with if the extension of the Metropolitan Supply which is now being urged is not consummated, but instead, the so-called Southern Sudbury and the Cochituate waters, now particularly unused, are filtered, mingled with the surface waters, and stored in the existing open distributing reservoirs in or near the city.

Some of us already know, and others may have heard rumors, that it is not a perfectly clean water which is being distributed at the present time from Spot Pond and Chestnut Hill Reservoir, — the two main distributing reservoirs, — owing to dust and bird droppings. There is a great deal of

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† Chief Engineer, Board of Water Commissioners, Hartford, Conn.

‡ Secretary, American Water Works Association.

§ Of Weston & Sampson, Boston, Mass.

¶ Of Metcalf & Eddy, Boston, Mass.

trouble from sea gulls, which seem to frequent those waters, especially Spot Pond, I believe, and which the State law does not allow to be shot. Keeping those ponds sufficiently clean to furnish a good water is a pretty hard proposition.

Of course those reservoirs are large. Spot Pond started as a natural pond; Chestnut Hill Reservoir has now been in use something like sixty years; and the processes of purification by sedimentation and aëration, that are common in large ponds, do go on to some extent in those reservoirs, where they are dealing with surface waters.

But what the condition is going to be when we have filtered waters, which are, of course, in effect artificially-produced ground waters, is a subject for concern on the part of the people who are interested in that subject.

Mr. H. C. Stevens.* A few years ago the city of Perth Amboy, N. J., built a distributing reservoir. I was associated with Mr. Johnson in its design and construction. The reservoir has a capacity of 40 mil. gal. and stores ground water for an average period of four days, within the city limits, with highways on either side. To keep dust, leaves and other matter from being blown in, and also to prevent the easy possibility of the bodies of animals being thrown into such a reservoir, it has always been our thought, as with most of us here, no doubt, that such reservoirs should be covered.

* Consulting Engineer, New York City.

PUBLIC WATER SUPPLIES OF VERMONT.

By Charles P. Moat.*

[*Read September 19, 1923.*]

Since 1899 when the Laboratory of Hygiene was established, it has been the policy of the State Board of Health to make frequent analyses of all water supplies that furnish water to ten or more families. These are the supplies that are classed as Public Water Supplies, although about 50 per cent. of them are under private ownership. During the last few years we have supplemented the laboratory examinations by field surveys as far as possible with our limited engineering staff.

When you consider that the total population of Vermont is approximately 350 000, a little less than half of which use water from our so-called public supplies and that many of these supplies are very small, you will see that our work of safeguarding these waters is far different and much easier than that of protecting supplies in more densely-populated places. Many of these supplies come from mountain springs and streams above habitation where the only human pollution can come from the careless hunter or fisherman. A field inspection on some of these sources often reveals deer tracks on the shore of a reservoir or stream well fenced to exclude cattle.

We have classed as public water supplies 106 supplies of our cities, towns and villages. Besides these supplies we aim to examine each season the waters used in our many vacation camps. We have approximately fifty of these camps in Vermont where 3 500 young people dwell for about two months in summer.

The sources of the 106 supplies are: — surface 31; ground 60; both surface and ground 15. Our laboratory data shows that the quality of many of these waters is unchanged in the past twenty years. Our data for 1920-21 indicate B. coli occasionally in 15 of the supplies, most of which is due to cattle pollution. Fifty-six can be classed as normal waters, 23 have received satisfactory natural purification, and 3 are classed as unsafe.

Our greatest improvement in water supplies was made in the few years following an order of the State Board of Health in 1904 which required the following cities and towns to obtain safe water.

Burlington taking raw water from Lake Champlain installed a filtration plant and its supply is now filtered and chlorinated.

* Chemist of Vermont State Board of Health.

St. Johnsbury using raw river water and a filtered water from Stiles Pond abandoned the former for domestic purposes after a court decision in favor of the State Board of Health.

Swanton changed from the polluted water of the Missiquoi River to the safe water of Fairfield Pond.

Enosburg Falls which had two supplies, one from a polluted river and the other from a safe spring supply, tried with poor success the double supply in each house, the spring water supply being inadequate to furnish water for all domestic purposes. At the present time, this village is taking steps to install a safe supply for all purposes.

Vergennes did not see fit to change from its polluted river water and despite action in court (still pending) still has a badly polluted supply.

The changes in these supplies brought about a big reduction in our typhoid rate.

Since these changes there has been a general improvement in a number of our supplies.

The only supplies being treated at the present time are:

Burlington — filtration and chlorination.

St. Johnsbury — slow sand filtration.

Rutland — chlorination.

Montpelier — chlorination.

A brief description of the supplies of our cities and large towns follows:

Burlington. Source — Lake Champlain. Filtered and chlorinated. Open storage reservoirs 6 500 000 gal. capacity — on hill above city. We get B. Coli pollution in our reservoir water during dry summer months which is accounted for by birds and dust from highway. Annual reports of our Water Department give account of this supply arranged in accord with our New England Water Works rules.

Vergennes. Polluted river water from Otter Creek — direct pumping system.

Winooski. Gravity supply from two open storage reservoirs supplied by springs, brook and four deep wells. Water is lifted from deep wells into reservoirs by compressed air using electric power for the compressors.

St. Albans. Gravity supply from two impounding reservoirs at No. Fairfax. One farm too near reservoir, although well kept up, impossible to avoid some wash from this place in spring thaws.

Newport. Gravity supply from Derby Pond. No direct pollution from few farms on watershed. Some boat and fishing on this pond.

Rutland. Gravity supply from mountain brooks and streams. Storage reservoir of 5 000 000 gal. Watershed populated and stream passes through farming country and along main highway. Chlorinated above storage reservoir.

Barre. Two gravity systems — with storage reservoirs supplied by small streams running through pasture land. Some chance for pollution from farms on one of these streams.

Montpelier. Gravity supply from Berlin Pond. City owns considerable land about pond but supply is open to pollution at pond and along stream to reservoir. Restrictions against bathing, boating and fishing on pond but have had trouble in enforcing them as they are contrary to local public opinion. New chlorination plant started to operate in July. Chlorinates direct to main below reservoir.

Middlebury. Gravity supply from springs and brook on mountain side. Springs are situated in uninhabited watershed. Brook which is used as auxiliary supply is open to pollution from road and few houses. Distribution reservoir of 1 000 000 gal. capacity.

Hardwick. Gravity supply from springs and streams flowing into storage reservoir. Watershed sparsely populated. Emergency supply from stream unsafe on account of highway and house drainage.

Island Pond. Gravity supply — 500 000-gal. storage reservoir on hills above town fed by springs in woods on mountain above reservoir.

Swanton. Gravity supply from Fairfield Pond. No direct pollution enters pond from few farms on water shed. Owing to poorly-constructed pipe line, there is difficulty at times in maintaining pressure.

Brandon. Gravity supply from mountain springs. Storage reservoir of 500 000 gal.

Fair Haven. Gravity supply from Inman Pond located in wooded land away from farms. Field survey shows evidence of fishing and picnic parties. Some algæ growth at times in this water.

West Rutland. Gravity supply from mountain springs and brooks. Storage reservoir. A spring in the village has been used in dry times but it is not sufficiently protected from surface wash.

Northfield. Gravity supply from mountain springs. 500 000 gal. reservoir.

Waterbury. Gravity supply from hillside springs above habitation 200 000 gal. reservoir. System sometimes fails in dry times.

Bellows Falls. Gravity supply from Minard Pond located in the hills above the village. No buildings on watershed. Proximity to town makes it tempting as a spot for picnic parties. Ice for village is cut on this pond.

Brattleboro. Gravity supply from Sunset Lake. There are a number of camps on shores of lake, but these are used by Brattleboro people and the Water Company has a caretaker to maintain sanitary conditions of privies, etc. Lake posted against bathing. From the lake the water flows in open brook through wooded and pasture land to open reservoir.

Windsor. Spring supply pumped by electric pump to storage reservoir of 300 000 gal.

Woodstock. Gravity supply — two storage reservoirs impounding waters from streams and springs. Watershed inhabited but there is no direct pollution from the farm buildings. Chance for cattle pollution.

You will note from the foregoing that there is nothing novel along engineering lines in these supplies, most of them being gravity supplies.

The analyses of the water from the various supplies throughout the state, may be found in the biennial reports of the State Department of Health.

Discussion.

Mr. Charles L. Pool.* I should like to ask if they have had any trouble in Burlington here with algæ, where the time of storage is not long enough or too long, or what the situation is?

Mr. Moat. No, we have not had any trouble. I think the water is admixed with fresh water often enough to take care of that. We do not get the taste and odors we used to get from our raw lake water. In those times we used to get a little taste and some odors, but at the present time we do not have them.

Mr. Frederic I. Winslow.† In this town you have a filtered supply from a surface source, uncovered. The present trend is towards covering this kind of supplies. Have you had any trouble here from taste and odors?

Mr. Moat. We have not had any trouble with them.

Mr. Winslow. Or growths?

Mr. Moat. Or growths. But covering the reservoir I think would do away with our accidental pollution on the hill, which I lay to birds and dust. But we have not had any trouble from taste and odor or growths in our supply.

Mr. Winslow. Then you would say you would only gain from very slight pollution by covering?

Mr. Moat. I think so. Are you as apt to get growths, taking the surface water and storing it in the open, as you are a ground water?

Mr. Winslow. No. In the report of Mr. Goodnough to the State, regarding the new Metropolitan Water Supply, he says, regarding covering filtered surface supplies, this is very important, but he nowhere says it should be done or ought to be done. I suppose it is a moot question whether you ought to cover a surface supply or not.

Mr. Frank A. Marston.‡ I should like to ask Mr. Moat a question. If I remember correctly, he mentioned several spring supplies by gravity. I known of one case where a town takes a number of springs into a supply by gravity, and they have a good deal of trouble from air getting in at the inlets at the springs. I was wondering whether the same trouble had been experienced in Vermont.

* Concord, N. H.

† Division Engineer, Metropolitan District Commission, Massachusetts.

‡ Of Metcalf & Eddy, Boston, Mass.

Mr. Moat. I do not know anything about it if it has. It has not come to our attention. It has evidently been taken care of locally if they have had that trouble.

Mr. Marston. Of course it would be a physical trouble rather than one of quality.

Mr. Pool. Mr. Moat spoke of blaming occasional findings of B. coli. on wild animals. This is often a vague but reasonable assumption to account for findings of B. coli in supplies from streams with watersheds above habitations or pasturage. I had an interesting experience recently in this connection which serves as a definite illustration of B. coli from such a stream being due to deer. At East Conway, N. H., a few coli were found in such a stream. There was nothing on the watershed to account for coli except a "deer yard" on the banks of the stream, reported by the superintendent. I told him I should like to see it, as I could scarcely believe that evidences of enough deer to cause the trouble could be found. We visited the "yard" and saw the scant remains of a large amount of deer dung which had been dropped on the banks close enough to be washed into the stream. Blueberry pickers had been detailed to remove the dung from the banks of the stream and about two bushels of the material had been picked up and placed in a pile below the dam. It had been on the ground, according to hunters, since last winter, and was dried up. I took some back to the laboratory and from the centers of some of the clumps, isolated B. coli readily. So there was no doubt that coli was coming from wild animals on this shed.

Mr. M. N. Baker.* Now that typhoid is so very much reduced, more and more attention is being given to other means of judging the quality of water supply, and every now and then there comes up something in regard to the coli or other bacteria which are found in water, which are probably due to birds or animals, or to dust blown into reservoirs, like the open reservoir here in Burlington.

Sir Alexander Houston, Director of Water Examinations, Metropolitan Water Board, London, England, in his annual report for 1922–23, details some studies he has been making on the infection from sea gulls and from fish in some of the many reservoirs that are used in connection with the Metropolitan Water Supply of London. In his attempt to determine whether the coli in the water were of human or animal origin, he made some extensive studies of bacterio-phages, but thus far nothing conclusive has come from these or his other attempts to determine whether the coli found in the water are of human or animal origin.

It is interesting for any of us who are familiar with water treatment in the United States to note in the yearly reports of Sir Alexander Houston the timid way in which he has been approaching chlorination and mechanical filtration. He took a plunge on chlorination at the time of the war because he was depending very largely upon storage for getting a safe

* Associate Editor, *Engineering News-Record*.

water supply, and to get the water to these storage reservoirs required a large amount of coal, and coal was at a premium during the war, and still is in England, as it is in this country. So he began chlorinating the water and thus reduced the pumpage to a considerable extent. Last year the London Water Board's coal bill was reduced $80 000 by chlorination and a lesser period of storage. In addition there was a saving on labor and other pumping expense. In earlier years the saving was larger, owing to higher prices.

But what seems almost comical to many of us here is the small-scale laboratory experiments on mechanical filtration that Sir Alexanter Houston is carrying on. It would seem on the face of it as if he was utterly ignorant of the extent to which mechanical filtration has been developed in America, but I do not suppose he is. He may feel quite confident of what mechanical filtration will do, but he has to convince a large Water Board, made up of delegates from the many cities and boroughs that are supplied with the London Metropolitan Water, and he has to go slowly, for he can't convince those people over there that just because Americans have done a thing on a large scale for a great many years it is safe. He is proceeding with these experiments, and he is not even using a coagulant, but he seems on the point, judging from his latest report of recommending to his Board a quite extensive use of mechanical filtration. He has a forward-looking mind, and his annual reports are among the most entertaining publications that come to my desk.

Mr. J. Frederick Jackson.* I should like to ask Mr. Moat a question. He spoke in his paper of suits that had been brought against different companies. My first question is, by whom were the suits brought?

And then he speaks again about regulations in regard to boating, bathing and fishing in some particular places. Will he kindly give us the limitations of the statute covering that? Does it cover the whole body of water, or is it restricted to certain portions of it?

Mr. Moat. The State Board of Health appeals to the Court of Chancery to enforce its orders, and then the case is tried in the Court of Chancery and then usually taken to higher courts. In the case of St. Johnsbury it was taken to the Supreme Court to determine the question whether the Board of Health could prohibit the use of a certain water, and the Supreme Court of Vermont ruled that we could. The bathing situation was also carried to the Supreme Court in the case of the Montpelier Water Supply, and was decided in favor of the State Board of Health. The boating and fishing case is still being fought out in the local courts of Montpelier. The first case that we brought against one of the men who had been boating and fishing is still pending. The Supreme Court sent it back to the lower court on account of some technicality in the Judge's charge, and it has not been re-tried. It is ready for re-trial at any time that the State's attorney wants to take it up.

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* Director, Bureau of Engineering, State Department of Health, Connecticut.

Mr. Robert Spurr Weston.* I should like to ask Mr. Moat a question along those lines. Whether or not the State Board of Health makes regulations for the governing of reservoirs for the local water departments?

And another question related to that, — whether he has noted any effects of the increased automobile traffic upon the quality of surface waters?

Mr. Moat. We usually make those regulations if asked for by the local authorities, or if the supply has potential danger enough, or has shown up enough in our laboratory results, plus the field inspection, to make us think that regulation is needed. In some of our supplies the posting seems to be done by the head of the local water department, but in others they have asked for a special ruling of the Board, giving them a notice prohibiting bathing, boating or fishing, or trespassing, and so forth, on their watershed, or the particular pond or reservoir that is in question. That is done by a special rule being made by the Board, and a notice to that effect being sent out and posted.

I have not noticed any additional pollution from the automobile traffic, but I expect to at any time. Our Rutland supply has worried us until we chlorinated it, and much more since we have the volume of automobile traffic coming over the main highway along which the Rutland supply runs. But since that supply has been chlorinated we feel a great deal safer about it than we used to. But I haven't any actual results that show that the automobile traffic has tended to pollute our supplies. I put the automobile traffic in the same class as the careless fisherman and hunter, and think they need very careful watching. I think that the streams that are available to that traffic should be well posted to show that it is a domestic water supply, if we do not do anything further.

*Of Weston & Sampson, Boston, Mass.

THE SUBMARINE PIPE LINE BETWEEN PORTLAND AND SOUTH PORTLAND, MAINE.

BY HARRY U. FULLER.*

[*Read September 19, 1923.*]

The city of South Portland is situated across the harbor from Portland. It has a population of 8 250, and uses about $1\frac{1}{4}$ mil. gal. of water daily.

The South Portland municipal water supply was built in 1892. A 12-in. main about 5 mi. in length carries the water from the Portland supply main to the heart of the city of South Portland. A standpipe with a capacity of 600 000 gal. was built near the center of the city, and the service was satisfactory until within a few years.

During 1920 and 1921 measurements of the use of water in different parts of the system, using a portable Simplex Pitometer, showed the necessity of not only improving the gridiron system, but of supplying a larger quantity of water in the more thickly settled parts of the system as a fire-protection measure.

Investigation of possible methods of supply indicated the advisability of laying a submarine pipe line across the harbor on the downstream side of Portland Bridge. It must be far enough from the bridge piers not to endanger them, and from the fender piers and electric cables to give room to work.

Two submarine power cables were moved upstream by having the diver attach lines at intervals of 50 ft. and pulling them alternately. The cables were moved about 20 ft., at a cost of about $200, without injury to them.

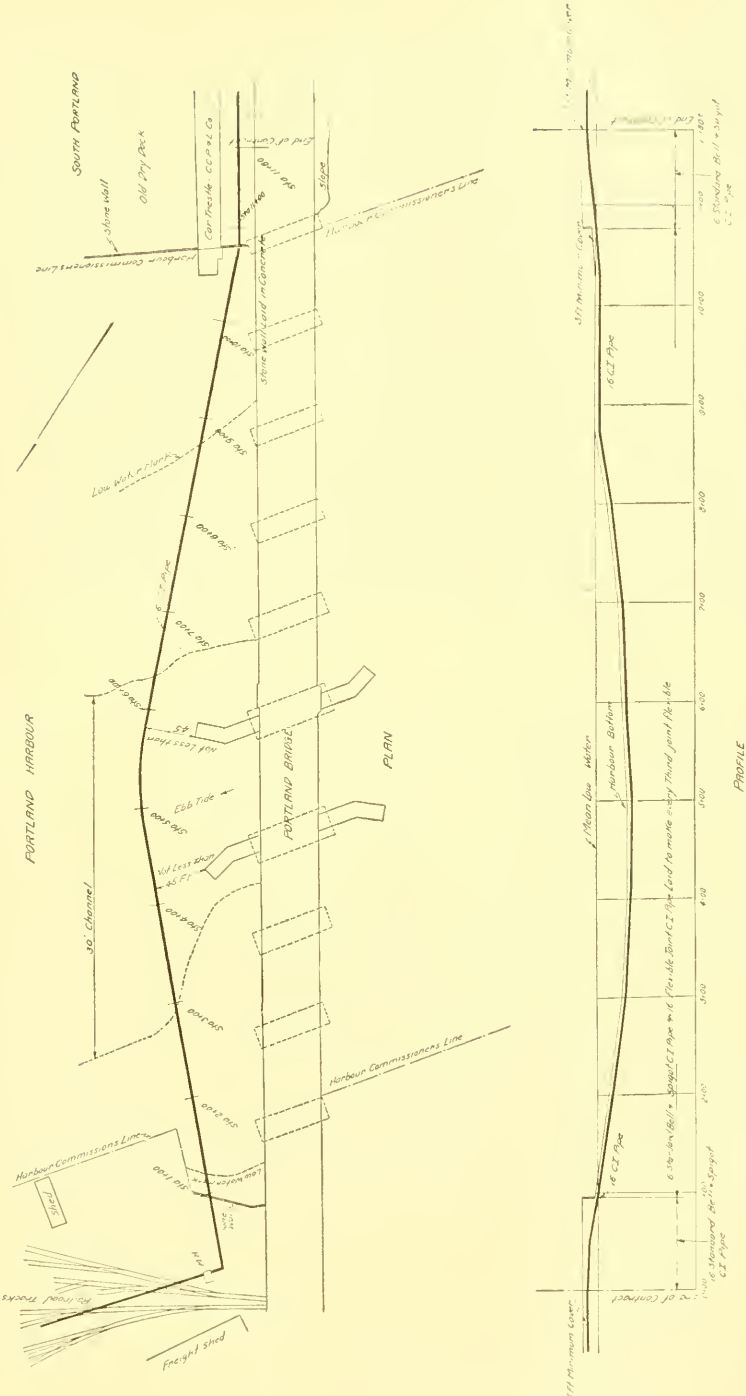
A study was made of the danger to pipes of freezing under sea water. The water in this harbor reaches 28° in the winter, and small pipes have been known to freeze when exposed to the action of the flowing tide.

Cans of fresh water were buried at different depths below the surface of the flats, and temperature readings were taken of their temperature during the winter. This evidence showed that a cover of 6 in. of the blue clay forming the harbor bottom was sufficient to insulate the warmer fresh ground water from the sea water.

Owing to the possibility of an anchor fouling the pipe, it was determined to have a minimum cover of 3 ft.

Sixteen-in. Class D American Water Works Association specifications cast-iron pipe was purchased by the Portland Water District and delivered to the contractor on a wharf near the job. Flexible joints were inserted

* Chief Engineer, Portland Water District, Portland, Me.



Plan and Profile of Pipe Line. — Scale 1 in. = 200 ft. approx.

in the line every 36 ft., or, in other words, every third joint was flexible. The improved Boston Metropolitan type of joint was selected. This is a form of flexible joint in which the lead is held firmly by grooves to the bell of the pipe, the motion being between the spigot and the lead joint.

The quality of the material forming the bottom of the harbor was investigated by sounding with a $\frac{3}{4}$-in. pipe. There was found to be a small layer, not over a foot in thickness, of silt underlaid with clay.

A piece of concrete was cast the size and weight of a piece of 16-in. pipe 1 ft. long and laid in the bottom of a hole excavated 2 ft. deep in the mud near low tide. This did not settle over $\frac{1}{2}$ in. and indicated that the pipe line would not settle materially in the clay to be found there.

Scope of the Work. The contract consisted of moving two submarine electric power cables, of dredging a trench and laying in it 1 000 feet of 16-in. submarine pipe, of back filling with a cover of 3 ft., and of trenching and laying a section of about 70 ft. in length of 16-in. pipe at each approach to the submarine line to connect with the existing pipe lines.

The depth of water was 35 ft. at low tide in the channel. On the Portland shore it was about 3 ft. deep, and on the South Portland end of the line about 200 ft. of mud flats were exposed at low tide.

Bids. Bids were received by the Trustees of the Portland Water District, August 28, 1922. They were as follows:

Bennett Contracting Corp., 211 Commercial St., Portland, Me.	$12,837
Roy H. Beattie, 10 Purchase St., Fall River, Mass.	13,377
The T. A. Scott Co., 292 Pequot Ave., New London, Conn.	20,959
Bay State Dredging & Contracting Co., 62 Condor St., East Boston, Mass.	29,365
Andrew S. Merrill, 20 Garden St., Bath, Me. (Informal bid)	16,200

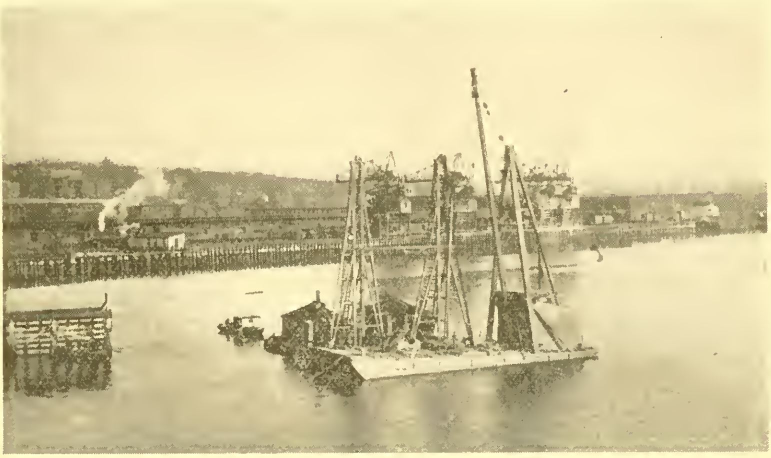
The contract was let to the lowest bidder. He was judged competent to do the work, and the outcome justified this action.

The following table shows the unit quantities and costs corresponding to the final estimate.

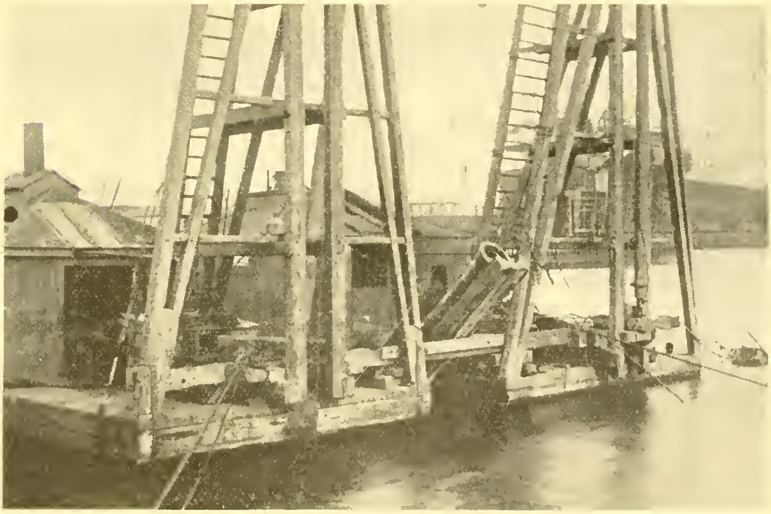
Item.	Quantity.	Unit Cost.	Total Cost.
Excavation on land	148 lin. ft.	$14.00	$2 072
Laying 16-in. cast-iron pipe on land	138 lin. ft.	1.75	242
Submarine excavation	1 007 lin. ft.	2.00	2 014
Laying 16-in. submarine pipe	1 007 lin. ft.	5.00	5 035
Back filling submarine trench	1 007 lin. ft.	.75	755
Moving electric cables	lump sum		200
Cutting through dock walls	lump sum		608
Lumber left in place	8 000 ft. B. M.	40.00	320
Gravel foundation submarine pipe	77 lin. ft.	2.00	154
Total cost of work			$11 400

Equipment. The contractor provided a derrick lighter 28 ft. x 80 ft. having an 83-ft. boom for dredging, pile pulling, pipe handling, and submarine back filling.

It was decided to lay the pipe by means of a chute suspended between two floating pile drivers. These two pile drivers were 20 ft. x 54 ft. and 24 ft. x 54 ft., each having 57-ft. pile-driving gins.



Lighter and Pipelayer Lashed Together.



Submarine Pipe in Cradle.

The dredging was done with a clamshell bucket. A dump scow was used to carry the excavated material from the channel portion of the job and deposit it on the flats nearby at high tide.

The pipelaying chute was 138 ft. long and 3 ft. wide. A portion of this chute, 126 ft., was built to a true circular curve of 207-ft. radius. The

upper 12 ft. was built straight, deflecting downward about a foot at the upper end, below the tangent to the curve, to facilitate obtaining straight joints when making the joint. The chute was built up of 5 lines of yellow pine timber bolted side by side. The middle line, or keel, was an 8-in. x 14-in. timber, hewed out on the top edge to the true curve. On each side of this keel were lines of 8-in. x 12-in. timbers, bolted flat against the keel with 1-in. screw bolts passing through the 3 lines of timbers, spaced about 18 in. apart and staggered. These timbers were about 23 ft. long and broke joints well.

The outside timbers of the chute were formed of 6-in. x 12-in. timbers bolted flat against the 8-in. x 12-in. timbers and projecting somewhat above the others to form sides to keep the pipe on the chute. These timbers were fastened by $\frac{3}{4}$-in. machine bolts passing through the 5 lines of timbers, spaced about 3 ft. apart.

On the hewed top surface of the keel was spiked a 6-in. x $\frac{1}{4}$-in. iron plate the entire length of the chute.

The two floating pile drivers were lashed abreast of each other with a 6-ft. space between, the gins being ahead. This was accomplished with timbers fastened across the decks at both bow and stern and diagonal wire cable across the space between. To keep them from listing, an 8-in. x 10-in. timber was lashed between the gins 30 ft. above the deck.

In the space between the two drivers was placed the vertically-curved chute with its lower end resting in the bottom of the trench and the upper end slung between the two gins of the pile driver. As an additional precaution, the middle of the chute was supported by lines running over sheaves at the stern of the scows, and thence over one of the gin heads and counterweighted with a 2 700-lb. pile-driver hammer moving up and down with the tide.

A long wire rope bale was attached to the lower end of the chute to provide a means of lifting it if it became necessary; but this proved to be a hindrance and not needed. In working on the flats, it became necessary to widen the space between the scows to 10-ft. and remove the timber lashed aloft between the gins that the scows might ground at low tide without undue strain.

The chute weighed about 10 tons, and was built vertically on a wharf, much like laying the keel of a boat.

Laying the Pipe. The Portland approach to the line having been laid by ordinary land methods with the end of the pipe projecting a few feet beyond the face of the sea wall, and the lighter having dredged a considerable length of submarine trench, the pipelayer was towed into position. The lower end of the chute was placed in the trench a few feet beyond the end of the approach pipe.

Two pieces of pipe were then placed in the upper end of the chute and the lead joints poured and calked.

A line was then attached to the lower end of the pipe laying in the chute, and the pipe pulled down the chute by a hoisting engine located on

Holding Unit of Three Lengths of Pipe While Making Joint.

Details of Pipelayer.

land. Another piece of pipe was then jointed into the upper end of the chute and pulled down the chute. This sequence of operations was then continued until the lower end of the pipe in the chute was inserted in the

bell of the approach line. A small sheet-pile cofferdam around this connection allowed the joint to be made in the ordinary way.

From this point the pipelaying consisted simply of adding successive lengths to the line in the chute and pulling the pipelayer along to keep pace with the pipelaying. In ordinary procedure the pipe was placed on the deck of the layer by the lighter, and then handled from the deck to the chute by a derrick boom attached to the side of one of the gins.

It was found necessary to have ten lines attached to anchors to hold the pipelayer in position against the force of the wind and tides. Two lines were required to pull the layer ahead, and a snubbing line was required to stop it at the right place. This snubbing line was attached to the pipe in the chute.

During the pipelaying, two spurts or dashes were made. The first spurt was across the channel, it being necessary to lay 192 ft. of pipe between the passage of ships without stopping. Right of way could not be obtained, but the channel had to be crossed when no vessel wished to pass. This was done between noon and 10 o'clock the same evening, and the operation furnished an excellent test of the possible speed of this method of pipelaying.

In preparation the lighter was lashed across the bow of the pipelayer, the three boats forming one unit. The trench having been properly excavated and inspected by the diver, only one other preliminary was attended to. Four sections of three pipes each and two sections of two pipes each were jointed together on the deck of the lighter, making units of 36 and 24-ft. in length. Strong backs or stiffeners, consisting of pieces of timber 6 in. x 8 in. x 12 ft. long with a saddle at the center and each end, were bound to the pipes with wire and prevented any movement at the joints while the units were being lifted into place in the chute. These units were handled by two whips from the lighter boom, and thus held in position while the lead joint was being run and calked. This method allowed a movement of 24 or 36 ft. for each joint poured in the chute.

The following tables were made from notes kept by the inspector. Table 1 shows the actual time required to make joints and pull the rig ahead, and Table 2 accounts for the entire elapsed time and explains the unforeseen delays.

Laying Submarine Pipe at Portland Bridge, November 9, 1922.

TABLE 1.

Showing Length of Time on Various Operations of Pipelaying.

							Total.	Average Time in Minutes.
Section No.	1	2	3	4	5	6		
No. of Pipe Lengths	3	3	2	2	3	3	16	
Length in feet	36	36	24	24	36	36	192	
Placing Section in Chute (min.)	8	10	12	8	10	7	55	9.1
Packing, Pouring and Calking Joint (min.)	19	14	18	20	18	16	1 hr. 45	17.5
Hauling, Rigging ahead (min.)	16	22	30	17	57	36	2 hr. 58	30.
Speed of Hauling ahead, feet per min.	2.25	1.64	.80	1.41	.63	1		1.28
Total	43	46	60	45	85	59	5 hr. 36	56

Laying Submarine Pipe at Portland Bridge, November 9, 1922.

TABLE 2.

Time Spent Laying Pipe Across Channel.

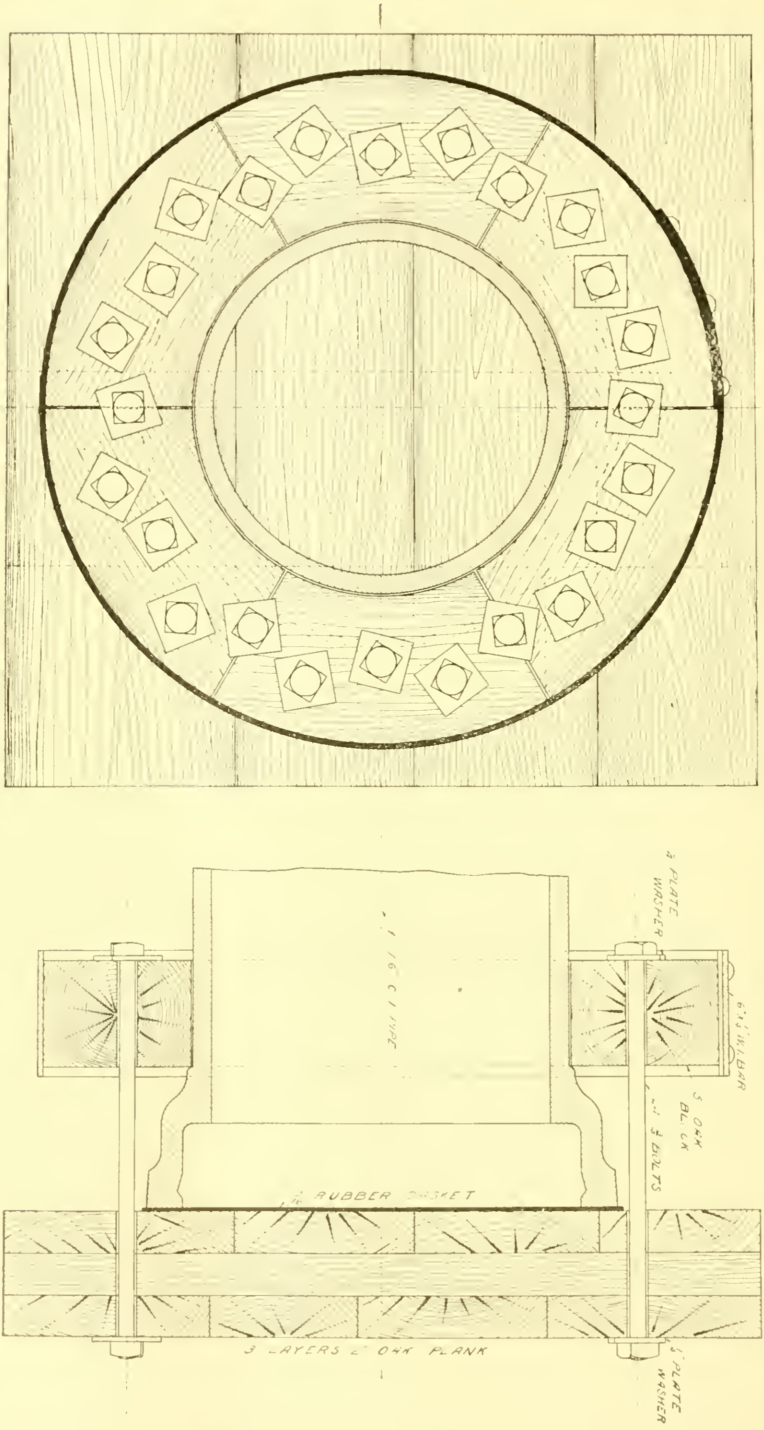
Time Mexican Petroleum boat passed through draw	12.17 P.M.
Time men quit at night	10.00 P.M.
Total elapsed time	9 hr. 43 min.

Time Actually Laying Pipe.

Moving lighter into position	33 min.
Moving rig ahead so that big bell would come in position in chute	26 min.
Placing 6 sections in chute	55 min.
Packing, pouring and calking 6 flexible joints	1 hr. 45 min.
Moving rig ahead 192 ft.	2 hr. 58 min.
Making lines fast for night	40 min.
Shortest time job could have been done	7 hr. 17 min.

Time in Delays.

Delay caused by yoke catching over stub in bottom of trench	1 hr. 20 min.	
Delay waiting for diver to get into suit	35 min.	
Delay putting on strong back	16 min.	
Lunch	15 min.	
Total delay	2 hr. 26 min.	
Total elapsed time		9 hr. 43 min.



DETAILS OF PLUG FOR 16-inch PIPE.

The second dash was made in order that the scows should either float freely in the channel or if grounded should be on fairly level flats free from large rocks. It was necessary to put in 7 lengths of pipe while the tide was rising and before it had fallen more than a few feet on the following ebb. This was successfully accomplished. After leaving the channel, and as the depth of water became less, the upper end of the chute was carried ahead with reference to the floating pile drivers and lashed in its new position. This was necessary in order that the bottom of the trench should not get too far from the tangent with the bottom of the curved chute. This was done three times and 23 ft. cut off from the upper end each time, leaving the chute 69 ft. long for its journey across the mud flats.

When a point was reached where the end of the pipe was about 40 ft. from the South Portland sea wall, it was held by a tackle and the chute pulled out from under it. A buoy was then fastened to the end of the pipe and it was lowered into the trench while a hole was made through the sea wall and the remainder of the trench excavated. The submerged end of the pipe was then raised and a section of 3 pieces of pipe previously jointed was connected in place. From this point the work was above low tide and done by ordinary land methods.

Testing. The specifications required that the leakage should not exceed 16.8 gal. per joint per 24 hr. for submarine joints, and 8.4 gal. per 24 hr. for land joints at a pressure of 150 lb. per sq. in.

A cap was made to fit the open bell end of the pipe while testing the line. It was composed of three layers of oak plank laid at right angles to each other and well spiked together, the whole cap being 3 ft. square. Between this cap and the pipe a sheet rubber gasket was placed.

Around the pipe and back of the bell was a collar of oak blocks 5 inches thick held in position by an iron ring 6 in. wide. Holding the cap to the collar were 24-$\frac{3}{4}$-in. machine bolts.

The line was tested three times during construction with the following results:

1st Test.

18 submarine joints	@	16.8 gal. =	302 gal. per day.
10 land joints	@	8.4 gal. =	84 gal. per day.
Allowable leakage			386 gal. per day.

The actual leakage was 5 400 gal. per day, or 14 times the allowable leakage.

2nd Test.

54 submarine joints	@	16.8 gal. =	907 gal. per day.
10 land joints	@	8.4 gal. =	84 gal. per day.

Allowable leakage 991 gal. per day.

The actual leakage was 4 280 gal. per day, or $4\frac{1}{3}$ times the allowable leakage.

3rd Test.

84 submarine joints	@ 16.8 gal. =	1 410	gal. per day.
19 land joints	@ 8.4 gal. =	160	gal. per day.
Allowable leakage		1 570	gal. per day.

The actual leakage was 2 540 gal. per day, or 1.6 times the allowable leakage.

The line was evidently growing tighter with time, and no attempt was made to calk the pipe under water.

Several months after the pipe line was completed, a further test was made by closing a valve on the South Portland approach to the submarine line and allowing the water to enter the Portland end of the line through a 2-in. meter. The leakage was found to be negligible.

Cost. The amount of the Bennett contract was $11 400. This was in payment for providing everything except the pipe and doing all the work necessary to complete the job.

Very good records were kept as the job progressed, showing the cost of the different items of work. They may be summarized as follows:

Dredging the trench, $2.00 per lin. ft.

Laying the submarine pipe, $5.00 per lin. ft.

Back filling the submarine trench, 75 cents per lin. ft.

While this work was progressing, abnormally good weather prevailed, and less than the usual number of unforeseen troubles to be expected on a job of this kind were encountered. While the contractor did not lose any money on the job, he did not make a profit proportional to his risks, or, in other words, his contract-price was too low, and he was fortunate not to lose.

Preliminary work was started the first week in September, and the job was entirely completed on December 22, 1922.

Personnel. The construction of this pipe line was done under the direction of Harry U. Fuller, the Engineer of the Portland Water District, with Leonard Metcalf as Consulting Engineer.

James W. Graham is Treasurer of the Water District, and Alfred E. B. Hall acted as inspector.

Discussion.

Mr. Frederic I. Winslow.* In testing that line did you close the gate and then connect a lead pipe around the gate to the main?

Mr. Fuller. Yes.

Mr. Winslow. How are you sure the shut gate did not leak?

Mr. Fuller. We were not sure. If there had been any leakage on the far end, our meter would have registered more, I should anticipate.

Mr. Winslow. Suppose the gate did not quite shut, was just open by a hair, we will say, and there was a leak in the pipe; the water might have passed through under the gate valve and not shown on the meter.

Mr. Fuller. I get your point. At the time that we closed the gate on the far end we emptied the pipe beyond the gate of water. We were putting a blow-off in at that time, so that there could not be any leakage from the far end into the pipe. There might have been a leakage from the big gate.

Mr. Winslow. We have usually tapped each end and then connected it up with the pipe and the meter, so that all water going into the test pipe must pass through the meter.

Mr. Fuller. We did that on the third test. This other test to which I referred was taken some little time later, after it was hooked up and we couldn't do it.

Mr. J. M. Diven.† How was the pipe protected from the action of salt water? Was any precaution taken to protect it?

Mr. Fuller. It was buried in a trench in the bottom of the harbor and covered with three feet of the blue clay that forms the harbor bottom.

Mr. Diven. Was the pipe protected from the action of the salt water in any other manner?

Mr. Fuller. We did not make any attempt to use anything other than ordinary coating.

Mr. Winslow. Did you state the weight of that pipe 12 ft. in length, the thickness?

Mr. Fuller. It was Class D pipe and had a special submarine joint. It carried 120 lb. of pressure.

President Sanders. Did you state, Mr. Fuller, how the back filling was done over this pipe?

Mr. Fuller. Through the channel portion we were not allowed to deposit our excavated material in the channel. In that section we put it into a scow and dumped it out onto the flats near low tide. Then after the line was satisfactorily in place we took up this mud from this pile in the water with our dredge and carried it back and put it down in the trench. But on either side of the channel, as we excavated the mud with our clam-shell bucket we swung the bucket around and deposited the mud perhaps

* Division Engineer, Metropolitan District Commission, Mass.

† Secretary, American Water Works Association.

50 ft. from the edge of the trench. We judged that would be far enough so that the tide would not carry it back into the trench before we wanted it there. Then when we came to backfilling we reached out, picked it up and put it back into the trench again. The scheme worked satisfactorily.

Mr. R. W. Wigmore.* I should like to ask if this sluiceway in which this pipe was sluiced, went down to the bottom — if that remained in the trench, or whether it was removed?

Mr. Fuller. We pulled the chute along as we went. That chute was attached, the upper end to the floating pile drivers, and the lower end in the bottom of the trench which had been excavated, which was about 6 to 8 ft. wide and 5 ft. deep. It was somewhat rough in the bottom, because it was dug with a yard or a yard and a quarter clamshell bucket. But a diver goes with this chute, dragging it along in the bottom of the trench to smooth off the irregularities. So that the chute was dragged along, and the pipe slid down the chute and slid off the end of the chute into the bottom of the trench. When we got to the end of the line we cut off some sections from the upper end of the chute, pulling the chute ahead as we did so until only about 80 ft. or 60 ft. of the chute was in position under the pipe. Then we held the end of the pipe up with one line and took a side hold of the chute with the other line, and found we could pull it sideways very easily. Then the chute floated up to the surface. Then we lowered after that the end of the pipe down into its position in the trench.

Mr. Wigmore. I was very much interested indeed, Mr. President, in this paper which has just been read. A number of years ago in St. John we laid a pipe from the mainland to an island in the harbor. On that island at that time were the Federal Government emigration buildings. It was not a success, and about 10 or 12 years ago a flexible copper pipe was laid from the mainland to the island. That has given considerable trouble the past few years on account of not being buried, and small boats anchoring in that channel in rough weather have broken it in a number of places. We are considering the laying of a cast-iron main there, and I am very much indebted indeed to Mr. Fuller for the paper which he has read, and I can see very clearly where, with the experience that Portland has had, we in St. John can profit.

President Sanders. I think Mr. Fuller's paper shows that he must have been considerable of a sailor, too, in addition to being an engineer, to handle that job.

Mr. Fuller. The real answer is that I was not much of a sailor or an engineer, but I knew how to pick out good ones of both kinds.

Mr. Frank A. Marston.† If Mr. Metcalf was here I am sure he could offer remarks more to the point, perhaps, than I can, although I was privileged to have a part in the studies that went on in a preliminary way.

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* Commissioner of Water and Sewage, St. John, N. B.

† Of Metcalf & Eddy, Boston, Mass.

One of the interesting questions which came up in the preliminary study of this proposition was the question whether the water in such a pipe line would freeze. Careful investigation was made, as far as possible, of available information on this subject, in connection with water pipes that had already been laid. The experience indicated that with pipe lines under salt water, larger than 6 in. in size, little trouble need be anticipated provided the pipe line is buried in the mud. The excellent experiments which were carried on by Mr. Fuller and his staff showed quite clearly that nothing need be feared in Portland harbor, under the existing conditions, with a 16-in. main and with the depth of covering of clay which it was proposed to give the pipe as a protection against anchors.

I do not think that I can add anything to the details which have been given so excellently by Mr. Fuller. I do want to offer a motion, however, Mr. President, which I believe is in order. Mr. Fuller has been very kind in coming and giving this paper, as a guest of the Association, and I offer a vote of thanks to him for his kindness.

(The motion was duly seconded and unanimously carried.)

SUB-SURFACE COLLECTING SYSTEM AND QUALITY OF WATER OF NEWTON, MASS.

By Edwin H. Rogers.*

[*Read September 19, 1923*]

Although the city of Newton, Mass., is within and a part of the Metropolitan Water District, which comprises nineteen municipalities in the eastern part of the Commonwealth, it is not a user of Metropolitan water except in emergency. Its municipally-owned-and-operated water works draws its supply entirely from underground sources located in the Charles River valley.

The collecting structures are located in a reservation in the adjacent town of Needham. The total area of the reservation is about 750 acres, but the portion thereof proven and demonstrated to be water-bearing gravel capable of practical development for yielding water does not exceed 150 acres, and it is within the limits of this area that the collecting system is located and draws its sub-surface supply.

This collecting system, as designed and constructed under the supervision of the city's engineering department, consists of a wooden collecting conduit built in 1889, a double line of open-joint 24-in. vitrified pipe laid in 1894, and a large concrete well constructed in 1911.

The wooden conduit is 4 ft. sq. in section, 3 769 ft. in length, laid level, with its invert grade line about 10 ft. below the average level of the river, which is in general from 50 to 75 ft. distant. This conduit is constructed of hemlock, green at the time it was used, and the planks composing its top, bottom and sides are laid with open longitudinal joints, permitting the water to infiltrate into the conduit from the adjacent water-bearing gravel. On either side of the conduit, $2\frac{1}{2}$-in. driven wells are located, reaching to depths of from 15 ft. to 80 ft. below the conduit and aid the flow of the ground water into the conduit. The top is generally 8 ft. below the ground surface.

From one end of this conduit, a cast-iron pipe line is laid under the river to the pumping station, which draws the water from the collecting system by gravity and pumps it directly into the distribution system. A ten-million-gallon reservoir located on top of one of the hills of the city controls the pressure, acting as a compensating reservoir and a reserve supply as well.

From the other end of the wooden conduit, a double line of open joint, 24-in. vitrified pipe is laid, and extends for 3 188 feet through nearly level land but little above the river level towards rising and hilly ground in a

* City Engineer

direction generally away from the river. The invert grade of these pipes is 2 ft. above the invert of the conduit at its start and rises on a slight grade, totalling 1.1 ft. in its whole length. They are laid 10 to 12 ft. below the surface of the ground. These pipe lines also have tributary 2½-in. driven wells, similar to the wooden conduit.

From the same end of the wooden conduit from which the pipe lines branch, is laid a tight conduit line about 3 570 ft. in length to the circular concrete well, 28 ft. in diameter, located about 500 ft. from the bank of the river, with its bottom about 32 ft. below the average river level. This well contains two 6-in. vertical, submerged, motor-driven, centrifugal pumps, which operate continuously a large part of the year and discharge about one million gallons of water per day into the wooden conduit through the pipe line by which it is connected.

The percentage of the supply contributed severally by the wooden conduit and the pipe lines is not known and difficult of determination; experiments are now under way to obtain this information approximately.

There are numerous manholes along both the wooden conduit and the 24-in. pipe lines, which afford an easy opportunity to observe the immediate ground water elevations. The elevations vary according to the seasons of the year and the conditions of rainfall, sometimes being only slightly below the river level and at other times from 4 to 5 ft. below.

A severe test of the adequacy of a ground water supply is increased use during summer months occasioned by shortage of rainfall at a time when the ground water table is low. The maximum draft on this supply in succeeding years for short periods of equal length has been increasing in a slightly diminishing ratio, in the period in question, while the total yearly consumption has been growing in a somewhat increasing ratio.

The total monthly quantity which the city may take from this reservation is limited by statute. This amount is variable within certain limits, as determined and approved by the State Department of Health, and is regulated according to the rainfall.

Analyses of the water as averaged for each five-year period for the past 30 years are as follows:

PARTS PER 100 000.

Years.	Appearance.		Residue on Evaporation.	Ammonia.		Chlorine.	Nitrogen as		Hardness.	Iron.
	Turbidity and Sediment.	Color.		Free.	Albuminoid.		Nitrates.	Nitrites.		
1893–1897	None	.03	5.68	.0004	.0023	.41	.0238	.0000	2.6	.012
1898–1902	None	.02	6.04	.0004	.0030	.45	.0357	.0000	2.5	.004
1903–1907	None	.05	6.30	.0008	.0040	.45	.0362	.0000	2.7	.011
1908–1912	None	.01	6.36	.0005	.0028	.48	.0251	.0000	2.7	.006
1913–1917	None	.02	6.79	.0008	.0037	.54	.0395	.0000	2.7	.006
1918–1922	None	.01	6.00	.0006	.0031	.43	.0299	.0000	2.4	.008
Average	None	.02	6.20	.0006	.0032	.46	.0317	.0000	2.6	.008

An examination of the average yearly analyses, plotted graphically, shows no curve indicating a deterioration in quality, but on the contrary that the average quality has been practically constant throughout this period for which data is available.

This description of this city's collecting system and analytical data as to the water produced is offered as an instance of a ground water drawn from a favorable locality, which shows but little variation in quality through a considerable period, and it may also be noted as a supply that has not deteriorated by reason of increasing hardness or iron content under constantly increasing demands. The maintenance of its quality is unquestionably due to the fact that it has not yet been drawn upon beyond its safe capacity at any time, but past and present conditions indicate that the restrictions imposed by the State Department of Health as to the quantity to be drawn are safe to follow, and conservatism as to any increased use of this supply is to be favored.

REPORT OF COMMITTEE ON WATER WORKS LEGISLATION.

To the New England Water Works Association,

Your committee appointed to report upon the water-works legislation of the Massachusetts General Court of 1923, submits the following:

The legislation desired for the purpose of facilitating the financing of municipal water works in accordance with the reports presented by a previous committee on January 9 and February 13, was not obtained. It developed, however, that the Commission on Municipal Expenditures and Taxation had given more attention to the arguments of our committee than had been anticipated, and in its report to the Legislature (dated February 15, 1923, House Document No. 1240) recommended that cities and towns be permitted to borrow for a period of twenty years, for the construction of filter beds, standpipes and reservoirs; and for a period of fifteen years for laying and relaying street water mains eight inches or more in diameter. This recommendation, with the backing of the Commission, some of whose members were also members of the Legislature, received more consideration than our committee's bill, and with some changes was enacted into law as Chapter 303 of the Acts of 1923. Section 1 of this act is the only one which especially interests this Association, and is as follows:

> Section 1. Section eight of chapter forty-four of the General Laws, as amended by section eleven of chapter four hundred and eighty-six of the acts of nineteen hundred and twenty-one, is hereby further amended, by inserting after clause (3) the following new clauses:—
>
> (3a) For the construction of filter beds, standpipes and reservoirs, twenty years.
>
> (3b) For laying and relaying street water mains of six inches or more in diameter, fifteen years.

Although this does not give all the relief which was desired, it constitutes a long step in advance and materially simplifies the matter of financing water-works construction under the General Laws.

Previous legislatures have repeatedly refused to pass legislation making water rates a lien upon property. This year, however, the legislature overturned an adverse report of its committee and passed an act (Chapter 391, a copy of which is appended hereto) making water rates of municipal plants a lien upon the property in cities and towns which accept the provisions of the act.

The Legislature passed an act (Chapter 453) to provide access for the public to great ponds, but specifically excepted from the provisions of the act all great ponds which are used as sources of water supply, so that the act, which might by its general terms have constituted a source

of danger to many public water supplies, became innocuous as far as water works are concerned.

It is significant to note that the bill to prohibit shutting off water for non-payment of water rates was given leave to withdraw.

With regard to extension of the Metropolitan water supply, the Legislature authorized its Committee on Water Supply to sit during the remainder of the year to consider this subject, and the employment of an engineer to advise and assist it.

Several acts were passed, providing for the incorporation of water companies or allowing the formation of water districts, or extending the time in which certain towns or water districts might construct water works. These are of no general interest. It is significant to note, however, that special legislation authorizing cities and towns to borrow for water-works purposes, for terms longer than stipulated in the General Laws, or for purposes not covered by them, were passed, as shown in the following tabulation:

SPECIAL LEGISLATION FOR MUNICIPAL WATER WORKS LOANS, MASSACHUSETTS LEGISLATURE OF 1923.

City, Town or District.	Purpose of Loan.	Amount Authorized.	Term of Bonds, Years.	Chapter.
Acushnet	Extensions of mains and improvement of distribution.	$65 000	30	42
Belmont	Extensions of mains and improvement of distribution.	100 000	20	80
Billerica	Extensions of mains and improvement of distribution and storage.	50 000	20	293
Dartmouth	Extensions of mains and improvement of distribution.	100 000	30	188
Hudson	Relaying and extensions of mains and improvement of distribution.	50 000	20	215
Marblehead	Increase of supply, filters, extensions of mains, standpipe, etc.	200 000	30	2
New Bedford	Intake gate house, screen basin, and extensions of mains.	350 000	30	65
Revere	Streets, sewers and water mains.	250 000*	10	367
Rutland	Extensions of mains and improvement of distribution.	50 000	20	275
Shrewsbury	Extensions and improvement of water system.	25 000	20	77
Swampscott	Extending and relaying mains and improvement of distribution.	50 000	30	134
Unionville	Extensions of mains and improvement of distribution.	5 000	10	444
Worcester	Increasing supply.	750 000	20	274

* Only part of this is for Water Works.

It is interesting to note that there were thirteen such special acts, nearly all of which were for extensions of the main pipes and improvements of the distribution system. The loans authorized ranged from \$5 000 to \$750 000, and the terms of the bonds from ten years to thirty years.

It is to be hoped that the enactment of Chapter 303 will, to a considerable extent, make such special legislation unnecessary in future.

Respectfully submitted,

CHARLES W. SHERMAN
ALBERT L. SAWYER
GEORGE A. KING

Committee.

JUNE 16, 1923.

[CHAPTER 391.]

AN ACT RELATIVE TO THE COLLECTION OF WATER RATES.

Be it enacted, etc., as follows:

Chapter forty of the General Laws is hereby amended by inserting after section forty-two the following six sections: — *Section 42A.* If the rates and charges due to a city or town which accepts this and the five following sections by vote of its city council or of the voters in town meeting for supplying water to any real estate at the request of the owner or tenant, including interest and costs thereon, as established by local regulations, ordinances or by-laws, are not paid within sixty days after their due date, the same shall be a lien upon such real estate in the manner hereinafter provided. This and the five following sections shall not take effect in a city or town accepting the same as aforesaid until the city or town clerk files in the proper registry of deeds a certificate that said sections have been so accepted. Each register of deeds shall record such certificate in a book to be kept for the purpose, which shall be placed in an accessible location in the registry.

Section 42B. Such lien shall take effect upon the filing for record in the registry of deeds for the county where the real estate lies of a statement by the board or officer in charge of the water department that the rates and charges for water supplied to the real estate therein described, including interest and costs, to an amount therein specified, have remained unpaid for sixty days after the due date, and said lien shall continue for one year from the first day of October next following. Such statement shall contain the name of the owner of record of such real estate and a description thereof sufficiently accurate for identification. The register of deeds shall receive and record or, in case of registered land, file and register, said statement.

Section 42C. Within a reasonable time after filing such statement for record or registration, the board or officer in charge of the water department shall commit the unpaid account with his warrant to the collector of taxes of the city or town, and such collector shall forthwith send notice in accordance with section three of chapter sixty to the person designated in such warrant as the owner of record, and any demand for the payment of such account shall be made upon such person. The collector shall have the same powers and be subject to the same duties with respect to such unpaid accounts as in the case of the annual taxes upon real estate, and the provisions of law relative to

the collection of such annual taxes, the sale of land for the non-payment thereof and the redemption of land so sold shall apply to unpaid accounts charged upon real estate under sections forty-two A to forty-two F, inclusive.

Section 42D. Unpaid accounts under sections forty-two A to forty-two F, inclusive, shall bear interest at the rate of six per cent. per annum from the time demand is made under the preceding section, or from such earlier time after their due date as the city or town may by ordinance or by-law provide. Any such account committed to the collector under said section and remaining unpaid shall be added by the collector to the annual tax bill next to be issued, and the total amount of such bill shall be subject to interest under the provisions of section fifty-seven of chapter fifty-nine.

Section 42E. An owner of real estate aggrieved by a charge imposed thereon under sections forty-two A to forty-two F, inclusive, in addition to such remedy as he may have under section ten of chapter one hundred and sixty-five, may apply for an abatement thereof by filing a petition with the board or officer having control of the water department within thirty days after demand under section forty-two C, and if such board or officer finds that such charge is more than is properly due, a reasonable abatement shall be made; and except as otherwise provided herein, the provisions of chapter fifty-nine relative to the abatement of taxes by assessors shall apply, so far as applicable, to abatements hereunder. If such petition is denied in whole or in part, the petitioner may appeal to the superior court for the county where the real estate lies upon the same terms and conditions as a person aggrieved by the refusal of the assessors of a city or town to abate a tax.

Section 42F. An owner of real estate who, in order to prevent the imposition of a lien thereon or to discharge the same, has paid charges for water furnished to a tenant or other person who was bound to pay the same, may recover from such tenant or other person in an action of contract the amount of the charges so paid with all incidental costs and expenses.

Approved May 15, 1923.

PROCEEDINGS.

The following is a synopsis of such parts of the proceedings at the Burlington convention as appears to be of value for the record.

Forty-Second Annual Convention.

Burlington, Vt.
September 18, 19, 20, 21, 1923.

The Forty-Second Annual Convention of the New England Water Works Association was held at Burlington, Vt., September 18, 19, 20 and 21, 1923.

The headquarters of the Convention were at the Hotel Van Ness, where the technical sessions were held and where the manufacturers had their exhibits.

The Convention was called to order on September 18, at 2 p.m., by Percy R. Sanders, the President, who introduced Mr. Jules Simays, Chairman of the Burlington Water Commissioners.

Mr. Jules Simays. Mr. President, Ladies and Gentlemen of the New England Water Works Association: It is a pleasure for me, and my good fortune, to appear before you here as the Chairman of the Water Commissioners of the City of Burlington, and to offer to you — well, we haven't much to offer except Champlain water, of which you may use all you wish and take some home if you want — we have plenty of it.

I have the honor at this time of presenting to you the chief executive of our city, Hon. J. Holmes Jackson.

Address of Welcome by Hon. J. Holmes Jackson, Mayor of Burlington.

Mr. Jackson. Mr. Chairman and Members of the New England Water Works Association: This city is honored by your presence. I assure you that our citizens appreciate your coming to Burlington to hold your Forty-Second Annual Convention. I hope you will find our city beautiful for situation and cordial in its welcome, and I trust and believe you will find the inhabitants of this city on Lake Champlain worthy of your acquaintance and confidence.

For forty-one years your Association has been considering one of the most important subjects connected with the prosperity of the people — namely, the protection of the public from the ravages of fire, and the providing of a pure water for domestic uses. Experience and the inter-

change of thought through these years as to the means and methods for securing the best results has made your services of the greatest value to humanity.

I notice your officers have prepared an extensive program, and I am sure you will make commendable progress in your work. Pure water and fire protection are the real safeguards of the community and the chief supports of its existence.

I bid you a most hearty welcome to our city.

Mr. Simays. Ladies and Gentlemen: I also have the pleasure of presenting to you the President of the Chamber of Commerce of the city, Mr. Ordway.

Address of Welcome by Mr. C. D. Ordway, President Chamber of Commerce.

Mr. Ordway. Mr. President, Ladies and Gentlemen of the Water Works Convention: I want to greet you with all the cordiality that can possibly be expressed in words, in the name of the Burlington Chamber of Commerce, to Burlington. We trust that your stay in Burlington will be made exceedingly pleasant by members of our organization.

Burlington is not the largest city in New England, quite, but we do boast of several things in Burlington that are pretty good size. One of those things is our water supply, which is practically inexhaustible — Lake Champlain. The other thing is that we can compete with any city, not only in New England but in the United States, in regard to the scenery and, I think, hospitality.

The Burlington Chamber of Commerce is a little bit unique in the fact that it is the only organization of its kind in the United States that has a thousand members to twenty-three thousand population. We leave that as a challenge until somebody disputes it, but as far as paid membership is concerned, I think it is the largest per capita organization of its kind in the United States. And this organization, while not every member is active, extends to you the greeting and the cordiality of its rooms, and anything that the Chamber of Commerce can legitimately do to further your organization and induce you to come to Burlington for future conventions we would be more than glad to do. We want to make Burlington a convention city, and we hope you will go away with such a pleasant taste in your mouth you will be glad to come back to us again in a very short time.

Response by President Sanders.

The President. Your Honor, Mayor Jackson, and Mr. Ordway: I wish to thank you this afternoon for your welcome to your city to the members of the New England Water Works Association.

In 1895, twenty-eight years ago, the New England Water Works Association held its fourteenth annual convention in your city, and it was

probably the memory of that convention which prompted a desire in the minds of those of our members who were at that convention to come again to your city to hold our convention.

I made my first trip to Burlington on Friday, the 13th of April, to see what could be done in reference to holding the convention here, and I am glad to say that that particular day will hold no fears for me in the future in making any trip.

The chief aim of the water-works manager or operator is not, as is popularly supposed, to dig up and spoil good streets, although I will admit that they do their share of that. It is, however, in the first place their aim, and you as citizens go to any expense to carry it out, to provide a pure and wholesome supply of water for domestic purposes and for fire protection. You spare no expense to do this, and then when it is done you place these works under the control and management of water-works superintendents and engineers. It is the main purpose and aim of this convention, and of all the conventions of the New England Water Works Association, to furnish a program dealing with water-works construction, sanitation, and all the problems of water-works management, so that we may more intelligently deal with the problems that come up before us.

I personally feel that it is one of the best investments that any city can make to send its representative, in the form of its manager or superintendent or engineer, to attend these conventions, because in that way he can meet with his fellow members and discuss his problems with them. In most cases the water-works superintendent is the only man in his town in his particular line, and he very often runs up against problems that can only be solved by a conference with his fellow members.

I wish to thank you again, Mr. Ordway, and your Honor, Mayor Jackson, for welcoming us here to-day.

Presentation of Honorary Membership to Mr. John Ripley Freeman.

President Sanders. The first thing on the program this afternoon is the presentation of Honorary Membership to Mr. John Ripley Freeman. It is the custom of this Association from time to time to bestow the grade, if I may call it so, of Honorary Membership upon some one of its members who has attained particular prominence in his profession or through his long association with this New England Water Works Association.

I will now call upon Mr. Charles W. Sherman, who will present to Mr. Freeman this Honorary Membership.

Mr. Charles W. Sherman. Mr. President, this is the first time that this Association has undertaken to confer Honorary Membership in a formal manner at one of its meetings. It is very much to be regretted that Mr. Freeman is not present. I had looked forward to the privilege of presenting him personally to receive this honor at your hands, but as it appeared at the last minute that he could not be here, and as the ceremony of the

formal presentation of Honorary Membership is something well worth while to establish, with the hope it may be perpetuated, I have asked our past president, Mr. Saville, to accept the Honorary Membership on behalf of Mr. Freeman.

I have looked forward to the privilege of making this presentation of Mr. Freeman with especial pleasure because it was my good fortune, at the beginning of my work in hydraulic fields, to work for some time under Mr. Freeman, and it would therefore have been particularly interesting to me to bring him up for such a presentation.

Mr. Freeman's name is well known to all hydraulic engineers, and to nearly all water-works men, as one of the greatest of our American hydraulic engineers. His work, as many of you know, has been more in other fields than that of water supply — particularly in fire protection, water power, the Panama Canal, the canals of China, the Charles River Basin, and works of that character. The water-works problems which he has dealt with, and with the greatest success, are, however, numerous and of the first magnitude. They include services as Consulting Engineer for the water supplies of New York City, San Francisco, Los Angeles, Baltimore, Hartford, and a number of the other of our very large cities.

Mr. Freeman's technical writings are also well known to many of us. Probably the best known are his two papers — one on "The Hydraulics of Fire Streams," and the other on "The Nozzle as an Accurate Water Meter," which were presented to the American Society of Civil Engineers about thirty-five years ago, and which, although as old as that, still remain the standards upon which practically all computations of hose and nozzles are based. The substance of the first of these papers was presented, somewhat abbreviated, to this Association, and published in our JOURNAL as well.

From the water-works standpoint it remained for the paper which he presented to us only, entitled "The Proper Arrangement of Hydrants and Water Pipes for the Protection of a City Against Fire," to make the number of the JOURNAL in which it appeared one of the "best sellers" for the time being, and the edition was quickly exhausted.

Mr. Freeman has been President of the Boston Society of Civil Engineers, of the American Society of Mechanical Engineers, and the American Society of Civil Engineers; and the New England Water Works Association will honor itself by conferring Honorary Membership upon him.

MR. CALEB M. SAVILLE. Mr. President, Ladies and Gentlemen of the New England Water Works Association: I trust if Mr. Freeman has arrived that he will come forward. I realize what a crescendo performance it is for anybody to substitute on such an occasion as this, and especially for such a genius as is Mr. Freeman. I believe that by conferring Honorary Membership on Mr. Freeman this Association has honored itself by honoring him.

It is unnecessary for me to add in responding for him, to what Mr. Sherman has said of the professional work of Mr. Freeman. That is well known throughout the world. I should like to tell you, however, of some of his personal traits, and I should like to have you know of some of his helpfulness to others.

Some years ago I spoke to him of his helpfulness to others, and I shall never forget the nice way in which he said to me, "That is all right, Mr. Saville; I had just such a feeling as that myself one time, a good many years ago, and I mentioned it to" — I think it was Mr. Hiram Mills — "and he said to me, 'The best thing that you can do, if you feel that way, it just to pass it along to the other fellow.'" And that has been Mr. Freeman's way of doing — to pass the good things along.

He has been of service to our own profession, to our water-works men most particularly, because he has been a water-works man. His first work, I think, was in Lawrence or Lowell — I have forgotten which — and from there he went with Mr. Edward Atkinson with the Factories Mutual Insurance Company — I don't know as I am saying these just in order, but I am just giving you the main sketch — and it was the result of his personal labors there that brought forth that splendid organization, with its laboratory and the experimental work which has now been brought to such perfection that its results are the criteria for this class of insurance.

Since that time Mr. Freeman has gone forward, until his name as Mr. Sherman has said, is well known everywhere. He has not been satisfied with just doing one thing well, he has advanced in many lines of business and professional work; his best has always been ahead of him.

It was said when he was engaged as the consulting engineer on the Charles River Dam he worked night and day on his report. There was no let-up to it until he got it completed, and that report is really one of the finest pieces of engineering literature of its kind.

His recognition of the work of others also is a very, very helpful thing to young men. When he reads something in a technical publication or in the scientific papers, busy man though he is, he is very quick to write a letter calling attention to the good points in that writing. That is tremendously helpful to the younger men coming along to find that a man of Mr. Freeman's standing is willing and able to recognize what they have done. Mr. Freeman is a man of impartial judgment, too. A man of strong convictions himself, he is very willing to give credit for what the other fellow has done.

He has been a student and an investigator, and many of the results that he has brought forward are now the standard for water-works engineering in this country.

I do not need to go further in this matter. Mr. Freeman is known, and, as I say, in honoring him you have honored yourselves in giving him this membership in your Association and I thank you in his name for it.

Award of Dexter Brackett Memorial Medal.

President Sanders. It is the custom at the Annual Convention to make the award of the Dexter Brackett Memorial Medal for the most meritorious paper written and read before this Association during the past year.

I will now call upon Mr. Frank A. Barbour, who will, in behalf of the Association, present this medal.

Mr. Frank A. Barbour. Mr. President, Ladies and Gentlemen: Your Committee by unanimous vote has awarded the medal for the year 1922 to Mr. Charles W. Sherman. We were forced to this award by the merits of his paper on "The Proper Term for Which Water Works Bonds Should Run," although we were somewhat embarrassed in looking over the history of the founding of the medal.

In 1916 Mr. Sherman made a motion before this Association proposing that a fund be raised to provide a memorial to Mr. Dexter Brackett. He was a member of the committee which was appointed; he handled the finances, and it was largely due to his efforts that the presentation of this medal is one of our yearly events. Despite these evidences of conspiracy, however, and particularly as Mr. Sherman has had the modesty to restrain his capacity for some six years — he did not take it the first year, and he has waited until this time — we were forced by the merits of the paper to make the award as we have done.

The paper was written under pressure, as I happen to know. It was written for a definite object. The object was to provide a scientific basis for an argument before the Legislative Committee in reference to a question of interest to all water-works men. It was written by a busy man, and it is a good example of what a busy man can do under pressure.

Mr. Sherman, it gives me very great pleasure, sir, to present to you this medal, which ought to be particularly valuable to you because of your intimate association with Mr. Brackett.

Mr. Charles W. Sherman. Mr. President, Mr. Barbour, Ladies and Gentlemen: I think any member of this Association is justified in feeling proud of being awarded the Dexter Brackett Medal.

As Mr. Barbour has said, I had a part in establishing a memorial to Mr. Brackett and determining what its form should be, but I never for a moment thought at the time that the medal would come to me. In fact, I thought the probability was so strongly against it that I took advantage of my position as a member of the committee to get the company, which made the dies and struck off the medals, to strike off one for me at my expense, marked "Proof," so that I might have a copy of it. It is, therefore, especially pleasing to have finally obtained a medal which is really given to me and which I did not have to buy.

The award of this medal brings to mind once more the work which Mr. Brackett did for this Association. The number of men who knew him

and knew what he did in that line is gradually decreasing, and it may not be out of place to say a few words about that. An appreciation of his work of course was the main reason why the Association decided to establish this memorial, and why our committee studied the form which such a memorial should take.

Mr. Brackett was not one of the founders of the Association. The original conception was, I believe, with a Mr. Lyon, who was president in the very early days of the Association and then practically dropped out, and had very little influence on its future work. The real formation of the society and its early history, its life, depended mainly on two men, who have now gone, Robert C. P. Coggeshall and Albert S. Glover. They were practically the founders of this Association.

Mr. Brackett may be said to have formed the Association's character. He took an active part in its work from, say, after the first five years, practically to the time of his death, and I think was responsible, probably more than any other one man, for making it a society which really accomplished something. And it was in recognition of that work that the committee finally decided that, as a memorial to him, something which recognized papers which tended to advance water-works practice was the kind of thing that Mr. Brackett himself would appreciate if he could know what we were doing.

Looking back on Mr. Brackett's career and what he did for the Association, it is with a feeling of a good deal of humility as well as pride that I accept this medal.

Election of Officers.

President Sanders. Under the Constitution under which we are now working, the year of the New England Water Works Association closes with the close of the Annual Convention, and it is the duty of the President, one hour after the opening of the convention, to declare the polls closed unless there are some who still wish to vote. If all have voted who wish, I will declare the polls closed and will ask Mr. Gidley, the chairman of the committee, to announce the count of the tellers.

Report of Tellers.

Mr. Henry T. Gidley, *Chairman.*

Total number of votes cast 249

President.

(To serve one year.)

David A. Heffernan, Milton, Mass. 246

Vice-Presidents.

(To serve two years.)

Theodore L. Bristol, Ansonia, Conn. 244

(To serve one year.)

Stephen H. Taylor, New Bedford, Mass. 242

Directors.

(To serve two years.)

George A. Carpenter, Pawtucket, R. I. 242
Arthur E. Blackmer, Plymouth, Mass. 232

(To serve one year.)

George W. Batchelder, Worcester, Mass. 244
Frank Emerson, Peabody, Mass. 227

Treasurer.

(To serve one year.)

Frederic I. Winslow, Framingham, Mass. 245

The President. Gentlemen, you have heard the report of the tellers. You have chosen as your President for the ensuing year, Mr. David A. Heffernan, and I know you will all be pleased to hear a few words from Mr. Heffernan.

Remarks by President-Elect David A. Heffernan.

Mr. Heffernan. Mr. President and Members of the New England Water Works Association: My thanks are due you, gentlemen, for the honor you have conferred on me in selecting me to preside over the deliberations of your Society for the coming year. I value the compliment especially as coming from a Society such as this, and I hope that with your hearty coöperation we shall keep up the good work of the Association as it has been carried on in the past. I thank you.

Mr. J. M. Diven. Mr. President, I have just read with a great deal of sorrow an announcement of the death of our long-time treasurer, Mr. Bancroft. I think that the Association should take some action and suitable resolutions should be prepared. Mr. Bancroft served this Association as treasurer for a great many years, well and faithfully.

Secretary Gifford. That has been taken care of.

President Sanders. I think it would be well for the members present to stand a moment in silence in reverence to Mr. Bancroft.

(All persons present stand in silence.)

On motion of Charles W. Sherman, duly seconded, it was voted, that the Executive Committee be authorized to reappoint or to revive the Association's committee to work with a corresponding committee of the American Water Works Association, on Meter Standardization, if in the judgment of the Executive Committee it seems wise to do so.

Mr. Henry V. Macksey. Mr. President, I think it is only proper at this time that we should congratulate the officers who have conducted this convention so well for us, and our members, not only active but associate, who have contributed so largely to the success of this part of the convention, and also that we should express our appreciation and gratitude to the local people who have helped so much in making the affair pleasant and profitable to all of us. Therefore, I offer the following resolution:

"That the thanks of the New England Water Works Association are hereby extended to Hon. J. Holmes Jackson, Mayor of Burlington; to C. D. Ordway, President of the Chamber of Commerce; to the Burlington Water Commissioners; and to the other officials and employees of the city of Burlington, to the members of the Honorary Reception Committee, the Local Committee of Arrangements, the Ladies' Committee, and to all others who have given so generously of their time and means to make this a most successful convention."

(The motion was duly seconded and unanimously carried.)

Mr. Theodore L. Bristol. Mr. President, it seems to me the Water Works Manufacturers' Association has helped a great deal to make this a delightful and successful meeting, and I therefore want to present a motion of thanks to them.

"Moved: That the thanks of the New England Water Works Association are hereby extended to the Water Works Manufacturers' Association, and to all the members of the Committee who have contributed so much to the success of this, the Forty-Second Annual Convention."

(The motion was duly seconded and unanimously carried.)

The following reports of the Association were received:

REPORT OF THE SECRETARY.

SEPTEMBER 1, 1923.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past eight months, and the general condition of the Association.

The present membership is 769, constituted as follows: 9 Honorary, 685 Active, and 75 Associate Members, there being a net loss for the year of 56. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1923.	Honorary Members	9			
	Died	1			
		—	8		
	Elected:				
	March	1	1		
			—		9
January 1, 1923.	Total Members		738		
	Withdrawals:				
	Resigned	22			
	Dropped	48			
	Died	9			
		—	79		
			—	659	
	Elected:				
	January	4			
	February	5			
	March	1			
	April	7			
	June	3	20		
		—			
	Reinstated:				
	Resigned in 1919	1			
	Resigned 1921	1			
	Dropped in 1918	1			
	Dropped in 1922	2			
	Resigned in 1923	1			
		—	6		
			—	26	
				—	685
January 1, 1913.	Total Associates		78		
	Withdrawals:				
	Dropped	6	6		
			—	72	
	Elected:				
	June	2	2		
	Reinstated:				
	Resigned in 1916	1	1		
			—	3	
				—	75

September 1, 1923.	Total membership	769
January 1, 1923.	Total membership	825
	Net loss	56

Members Elected from January 1, 1923, to September 1, 1923.

January. Arthur L. Gammage, Walter F. Garland, E. C. Hopkins, Thomas W. Proctor. (4)

February. Dexter P. Cooper, Charles E. Kendall, Harry N. Lendall, Daniel M. Sullivan, George G. Weeks. (5)

March. Harry E. Holmes. (1)

April. N. J. Beisel, Harold C. Chandler, Harry T. Foley, Frank Hartman, R. W. Hendricks, George O. W. Servis, Robert L. Totten. (7)

June. Martin G. Ferry, Thomas Hersom, Jr., William P. Melley. (3)

Reinstated:

Dropped in 1918, George A. Stowers	1
Dropped in 1922, Samuel A. Agnew and Earle Talbot	2
Resigned in 1919, Horace J. Cook	1
Resigned in 1921, James H. Mendell	1
Resigned in 1921, J. Frank Ellis	1
	6

Associates.

June. Lap-Joint Impervious Pipe Co.; McWane Cast Iron Pipe Co. (2)

Reinstated:

Resigned in 1916, Ware Coupling and Nipple Co. (1)

Honorary Member.

Died: Rudolph Hering. (1)

Members.

Died: David Dexter Clarke, Frank E. Hammond, Frank W. Hodgdon, Louis H. Knapp, William H. Pitman, William D. Pollard, James T. Stevens, Herbert M. Tucker, Henry A. Young. (9)

Resigned: Forrest E. Bisbee, J. H. Bridgers, Walter I. Brown, Guy Eldredge, Ivan Escott, Timothy E. Hopkins, William F. Hunt, T. J. McCarthy, Henry Newhall, Harold S. Palmer, Henry E. Perry, Charles E. Perry, William E. Perry, William J. Roberts, F. W. Schwartz, Arthur H. Smith, Charles H. Smith, T. V. Sullivan, Russell Suter, Arthur S. Tuttle, L. C. Wright, Adolph V. Zehr. (22)

Dropped: A. D. Adams, G. M. Bacon, C. H. Bartlett, C. S. Beaudry, C. A. Bingham, C. P. Birkinbine, S. W. Borden, Philias Brunelle, F. L. Cole, G. W. Cutting, Ernest Drinkwater, Edmund Dunne, B. R. Felton, C. H. Fischer, W. D. Frederick, W. E. Fuller, P. T. Gray, G. G. Hare, W. H. Jackson, H. R. Johnson, W. A. Keene, J. F. Kidder, H. C. Kinney, J. S. Langthorn, E. J. Looney, W. E. McDonald, Charles McLenna, A. M. McKenzie, Henry Manley, L. P. Marshall, S. J. Mason, E. L. H. Meyer, C. W. Mills, A. J. Mylrea, E. B. Norton, M. S. O'Leary, W. J. Orchard, W. H. C. Ramsey, F. H. Robbins, S. A. Sewell, F. N. Strickland, A. H. Sutherland, D. H. Townley, H. R. Turner, Morrell Vrooman, F. O. Walker, N. M. West. (48)

Associates.

Dropped: Allen & Reed, Inc., American Manganese Co., East Jersey Pipe Corp., Lock Joint Pipe Co., Robert Filter Mfg. Co., Van Gilder Water Meter Co. (6)

Honorary Member.

March. John Ripley Freeman (elected). (1)

Receipts from January 1, 1923, to August 31, 1923.

Initiation fees			$116.00
Annual Dues:			
Members	$3 943.09		
Associates	1 460.00		
		$5 403.09	
Fractional Dues:			
Members	$34 00		
Associates	10.00		
		44.00	
Past Dues	$14.00	14.00	
Total Dues			$5 461.09
Advertisements			2 589.00
Subscriptions			212.00
JOURNALS sold			149.75
Sundries			111.94
Total			$8 639.78
There is due the Association:			
Advertisements			$43.00
JOURNALS			6.25
Reprints			119.60
Subscriptions			8.00
Total			$8 816.63

FRANK J. GIFFORD, *Secretary.*

REPORT OF THE TREASURER.

January 1, 1923 to August 31, 1923.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$187.89
Initiation fees	$116.00	
Dues	5 461.09	
Total received of members		5 577.09
Received from Estate of Hiram F. Mills		517.50
JOURNAL:		
Advertisements	$2 589.00	
Subscriptions	212.00	
JOURNALS sold	149.75	
Sale of reprints	31.00	
Total received from JOURNAL		2 981.75

Miscellaneous:		
Sale of "Pipe Specifications"	$11.75	
Membership lists	3.00	
Certificates of membership	21.00	
Interest (Old Colony Trust Co.)	5.02	
Index	1.00	
June outing	8.00	
Cuts	20.00	
Meter rate sheets	1.00	
Postage (From Affiliation)	10.17	
Total		80.94
Total receipts		$9 345.17

Expenditures.

JOURNAL:		
Advertising agent's commission	$245.20	
Plates	871.59	
Printing	1 987.65	
Editor's salary	225.00	
Reporting	104.04	
Advance reports	56.50	
Reprints	439.10	
Stationery and postage	86.59	
Miscellaneous	5.71	
		$4 021.38
Office:		
Secretary's salary	$133.33	
Affiliated Societies	985.06	
Secretary's expense	19.63	
Assistant Secretary's expense	16.63	
Printing, stationery, and postage	113.14	
Membership lists	16.00	
		1 283.79
Meetings and Committees:		
Stereopticon	$14.50	
Dinners for guests	17.00	
Music at dinners	32.50	
Printing, stationery, and postage	147.12	
		211.12
Treasurer's salary	$33.33	
Certificates of membership	7.50	
Miscellaneous	39.50	
Exchange	.45	
		80.78
Total expenditures		$5 597.07

FREDERIC I. WINSLOW, *Treasurer*.

In account with the New England Water Works Association.

RECEIPTS.

1923.			
Jan. 1.	On hand (includes Lake Shore & Michigan Southern bonds)		$5 581.61
	Received from Secretary		8 639.78
	Interest on bonds and deposits		187.89
	Estate of Hiram F. Mills		517.50
			$14 926.78

EXPENDITURES.

Bills paid		$5 597.07
ON HAND.		
Framingham National Bank	$1 511.14	
Liberty Trust	1 765.94	
Franklin Savings, Boston	1 000.00	
Farmers & Mechanics Savings, Framingham	1 521.25	
People's, Worcester	1 466.53	
Mechanics, Reading	249.85	
Bonds Nos. 2642 and 2644 Lake Shore & Michigan R. R. 4s, due May 1, 1931	1 815.00	
		$9 329.71
		$14 926.78

ASSETS AND LIABILITIES.

ASSETS.

Cash in Banks		$7 514.71
Lake Shore & Michigan Southern bonds (above)		1 815.00
Accounts receivable:		
Advertisements	$43.00	
JOURNALS	6.25	
Reprints	119.60	
Subscriptions	8.00	
		176.85
		$9 506.56

LIABILITIES.

Surplus	$9 498.11
Bills payable	8.45
	$9 506.56

FREDERIC I. WINSLOW, *Treasurer*.

Report of Auditing Committee.

We have examined the accounts of the Secretary and the Treasurer of the New England Water Works Association, and find the books correctly kept, and the various expenditures of the past eight months proven by duly approved vouchers. The Treasurer has also accounted to us for the investments and cash on hand, as submitted in the above reports.

A. R. HATHAWAY,
E. D. ELDREDGE,
Finance Committee.

Report of the Editor.

To the New England Water Works Association: I present the following report for the Journal of the Association for the March and June issues of 1923. This report covers the total charges and accounts receivable relative to the above issues and is required at this time because of the change in the fiscal year.

The accompanying tabulated statements show in detail the amount of material in these Journals or partial volume.

Size. — The numbers contain 328 pages.

Reprint. — Fifty reprints of each paper have been furnished to the author where desired.

Circulation. — The present circulation of the Journal is:

Members, all grades	769
Subscribers	98
Exchanges	14
Total	881

A loss of 50 since December, 1922. Journals have been sent to all advertisers.

Advertisements. — There has been an average of 36 pages of paid advertisements with an income of $1 661.50, an increase of $91.00 over the average of two issues of 1922.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $4.00 have been sold, and payment received of $7.75 for specifications sold in 1922, but not noted in Editor's report for last year. The net gain by actual receipts up to December 31, 1922 was $343.35, so that total net gain from this source to date is $355.10 and 4 copies on hand, $1.00 worth if sold at retail.

Post Office Account. — The Association has a credit of $2.38 at the Boston Post Office, being the balance of money deposited for payment of postage.

TABLE 1.

STATEMENT OF MATERIAL IN MARCH AND JUNE, 1923, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Date.	Pages of								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total	Total Cuts.
March	111	21	132	..	41	4	0	177	10
June	100	6	106	..	41	4	0	151	33
Total	211	27	238	..	82	8	0	328	43

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF MARCH AND JUNE, 1923, ISSUES OF JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.

Advertisements	$1 674.50
Sale of JOURNALS	149.75
Sale of Reprints	31.00
Subscriptions	212.00
Cuts	20.00
Index	1.00
	$2 088.25
	341.14
	$2 429.39

Expenditures.

Advertising agent's salary and commissions	$165.20
Plates	113.86
Printing	1 686.29
Reporting	104.04
Mailing-Postage	40.35
Editor's salary	150.00
Editor's incidentals	23.30
Reprints	120.60
Wrapper	25.75
	$2 429.39

HENRY A. SYMONDS, *Editor.*

TABLE 3.

COMPARISON BETWEEN MARCH AND JUNE, 1923, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.	Vol. XXXV. 1921.	Vol. XXXVI. 1922.	March and June issues of Vol. XXXVII 1923.
Average edition (copies printed)	1 000	1 050	1 325	1 500	1 388	1 200	1 150	1 100	1 100	1 100
Average membership	745	803	904	1 002	954	902	885	864	826	797
Circulation at end of year	858	951	1 079	1 155	1 010	1 002	970	929	929	881
Pages of test	554	564	596	538	398	566	359	399	618	238
Pages of text per 1 000 members	746	702	659	538	417	627	406	462	748	298
Total pages, all kinds	733	719	776	707	557	726	520	560	801	328
Total pages per 1 000 members	984	895	859	707	584	805	588	648	970	412
GROSS COST:										
Total	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$4 967.99	$5 011.03	$5 381.84	$6 354.10	$2 429.39
Per page	4.89	4.65	5.47	4.79	5.59	6.84	9.64	9.61	7.93	7.41
Per member	4.81	4.17	4.68	3.38	3.26	5.51	5.66	6.23	7.69	3.05
Per member per 1 000 pages	6.46	5.80	6.02	4.79	5.85	7.59	10.88	11.12	9.60	9.29
Per member per 1 000 pages text	8.68	7.39	7.85	6.30	8.19	9.74	15.77	15.61	12.47	12.81
NET COST:										
Total	$1 322.90	$1 155.33	$1 091.09	$1 171.98	$694.54	$2 675.04	$1 722.14	$1 869.85	$2 434.26	$341.14
Per page	.80	1.61	2.70	1.65	1.25	3.68	3.31	3.34	3.04	1.04
Per member	1.78	1.44	2.32	1.17	.73	2.97	1.95	2.16	2.95	.43
Per member per 1 000 pages	2.42	2.00	2.98	1.65	1.31	4.09	3.75	3.87	3.68	1.30
Per member per 1 000 pages text	2.42	2.38	3.88	2.17	1.83	5.25	5.43	5.43	4.77	1.80

President's Address.

Mr. Percy R. Sanders. Gentlemen: You have listened to the reports of the secretary, the treasurer and the editor for the eight months ending September 1, 1923.

By the secretary's report you will note that our total membership is 768, composed of 9 honorary members, 684 members and 75 associate members. We have lost by death, 1 honorary member and 9 members. We have lost by resignation, 22 members; 49 have been dropped for nonpayment of dues and 6 associates have been dropped for the same reason. These resignations and withdrawals may be traced in most cases to a transference of activities to some other line of work. By death, resignation and withdrawals, our net loss is 57.

Beginning with June 1, 1923, we started on our second year as a member of the Affiliated Technical Societies of Boston. This Affiliation is composed of the following societies:

Boston Society of Civil Engineers,
New England Water Works Association,
Plant Engineers Club,
Boston Section American Institute of Electrical Engineers,
Boston Section American Society of Mechanical Engineers,
Northeastern Section American Society of Civil Engineers,
Boston Section American Institute of Mining and Mechanical Engineers,
Massachusetts Chapter American Society of Heating and Ventilating Engineers,
Boston Chapter American Association of Engineers.

The Affiliation has its chairman, two vice-chairmen, treasurer, clerk and an executive secretary. It also has a council consisting of two members from each organization.

A review of just what membership in this Affiliation constitutes may be of interest to our members, and as we closed our first year on May 31, we can give concrete figures pertaining to the expenses of the New England Water Works Association membership in the Affiliation.

Prior to June 1, 1922, the affairs of our Association were conducted practically as they are at present with the exception of the office of secretary. The headquarters of the Association were in Tremont Temple for which a rental of $750 per year was paid. An assistant to the secretary was employed at an annual salary of $1 200 who devoted her entire time to the work of the New England Water Works Association. The average yearly expense of these two items will be seen to have been $1 950.

Upon becoming a member of the Affiliation, headquarters were continued as before in Tremont Temple, but the assistant to the secretary ceased to be an official of our Association and became a clerk of the Affiliation. Provision was made for the payment of rent and clerical work in the form of an assessment of $3 per member. If any member of the Association was also a member of any of the other affiliated organizations, the dues were allocated in proportion to his membership.

For the year ending May 31, 1922, the amount paid the Affiliation was $1 982.96.

Our membership January 1, 1917, was 1 043; September 1, 1923, or nearly seven years later, it is 768, a loss of 275 members.

Our need is new members to take the places of those who have dropped out by reason of death, resignation or otherwise, and the question is, how are they to be secured?

At the close of this convention, we start out with a new constitution which, while not differing materially from our former one, still makes some changes. The executive force is reduced, and the year, instead of beginning January 1 and closing December 31, will begin at the close of the annual convention, continuing until the close of the next.

This brings forward the thought, has not the time arrived when the several paid officers of this Association should be combined into one, whose incumbent would devote his entire time and energies to the welfare of the New England Water Works Association? I believe that a committee should be appointed to consider this matter thoroughly and make such recommendations as it thinks advisable.

I wish to thank the officers and members of the Association for their assistance and coöperation during the year and also the members and friends who have furnished the papers for our meetings. The printed record of our papers and discussions will always be a source of gratification to me and will recall memories of strengthened friendships and pleasant labors.

EDWARD JAMES CHADBOURNE.

Edward James Chadbourne was born in Wiscassett, Maine, October 5, 1848, and died September 17, 1922.

He was educated at Oak Grove Academy, Vassalboro, Maine, and at Kent's Hill Seminary, Maine.

He joined the New England Water Works Association on June 11, 1885.

He superintended the construction of the Hingham and Nantasket, Spencer, Wakefield and Stoneham Water Works Systems. He later acted as superintendent of Water Works for Holbrook and Randolph, also Wakefield and Stoneham.

He was associated with the Coffin Valve Company of Neponset for over fifteen years.

At the time of his decease he was senior member of the firm of Chadbourne-Walker Machine Screw Co., 100 Sudbury Street, Boston, and resided at 6 Walnut Street, Reading.

He married Sarah A. Beless of Needham, May 14, 1873. Two daughters survive him, Mrs. Arthur L. Wiley of Wakefield, Mass. and Mrs. Edward H. Sawyer of Cambridge, Mass., and one grandson, Arthur Lyman Wiley, Jr.

Mr. Chadbourne pursued a very varied and active life. He accomplished much in the line of Water Works construction. Manufacturing also appealed to him very strongly. He was an honest, able man, respected and highly esteemed by all who had the good fortune to know him.

New England Water Works Association

ORGANIZED 1882.

Vol. XXXVII. December, 1923. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

RAPID SAND FILTRATION AT CAMBRIDGE, MASS.

BY GEORGE A. JOHNSON.*

[*Read September 19, 1923.*]

Twenty-one years ago the first rapid sand filter plant wherein the filter tank units were built of concrete, rectangular in plan, and where the design of the entire works revolutionized the art of rapid sand filter construction, was placed in operation at Little Falls, N. J. This splendid plant set the pace for all future construction of this type, and it is somewhat remarkable that since then the basic features embodied in that plant have not been departed from in the hundreds of installations of rapid sand filters made in the United States in the past twenty years. The Little Falls plant is still doing in a highly satisfactory manner the work for which it was conceived, designed, and erected. When it was built it was freely predicted by many that about all that could reasonably be expected in future plants of this type would be developments of detail, and this has turned out to be generally true.

The speaker was fortunate in having resident charge of the management of the Little Falls plant from the day on which it was placed in operation until all parts of it were running smoothly. After the first six months of continuous operation the management of the works was turned over to Mr. Frank W. Green, who for over twenty years has proved himself an exceptionally competent, ingenious, resourceful superintendent.

On June 28 of this year the new water purification works of the city of Cambridge were dedicated, and that occasion marked an epoch in the history of sanitary engineering in the Commonwealth of Massachusetts. The Cambridge works are the first installation of a municipal water filtration plant of the rapid sand type to be made in that state for the expressed purpose of protecting the health of a community and giving the consumers a clean water.

The plant has been in full operation since April 14 of this year. The results obtained thus far are concordant with the predictions made by the

* Consulting Engineer, New York.

Fig. 1. General View of Filter House.

speaker when the designs were prepared in 1915, as is borne out by the records of Mr. Melville C. Whipple of Harvard University, who supervises the operation of the works.

Twelve years ago filtration of the Cambridge water supply was recommended by Mr. Frederic P. Stearns, Prof. Hector J. Hughes of Harvard, and Mr. Lewis M. Hastings, City Engineer of Cambridge. Two years later, after an investigation of the watershed, Profs. George C. Whipple and J. W. M. Bunker of Harvard also recommended filtration. In 1915

FIG. 2. FILTERS.

the Cambridge Water Board recommended to the then Mayor and now Superintendent of the Water Department, Hon. Timothy W. Good, that such improvements be made, and the speaker was engaged to engineer the job.

Plans for a rapid sand filter plant were submitted to the Water Board on October 15, 1915, and the ensuing fourteen months were occupied in hearings by the State Board of Health at which various and sundry criticisms by that body of the project as planned were discussed without definite issue. Suspension of all other than absolutely necessary public-works construction during the World War caused further delay until the present Mayor, Hon. Edward W. Quinn, recommended appropriation of the necessary money for construction which was granted by the City Council in 1920. Contracts were executed on June 28, 1920, with Coleman Bros., Inc., of Boston, and the Roberts Filter Manufacturing Co. of Darby, Penn.

Ground was broken early in July, 1920, and thereafter construction proceeded rapidly until stopped by the severe winter of that year, during which no work was done for ninety consecutive days. The plant was finally ready for operation on April 6, 1923, and was started in full operation on April 25, and officially dedicated on June 28, 1923.

Source of Supply. The Cambridge water supply is derived from a watershed lying in the vicinity of Waltham, Weston, and Lincoln, upon which there is a resident population of some 30 000. The drainage area

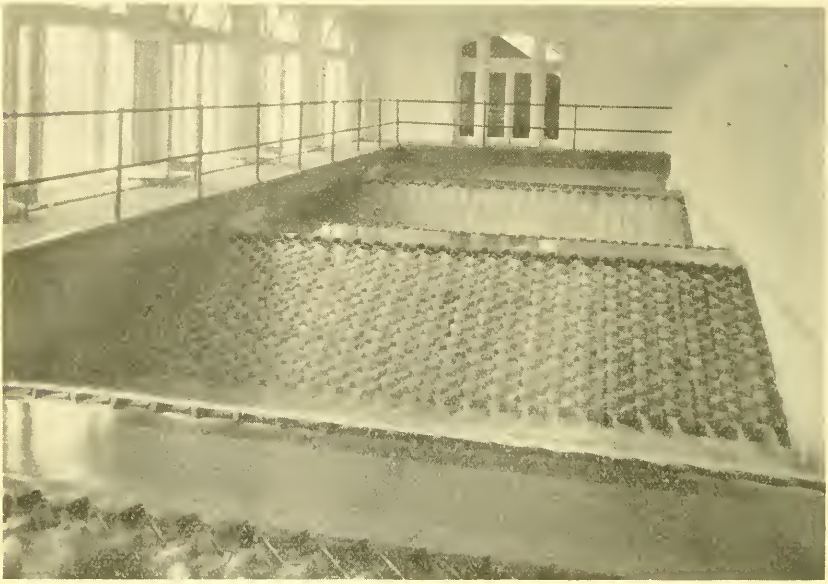


FIG. 3. AËRATOR.

above the diversion point covers 23.57 sq. mi. The waters of Hobbs Brook and Stony Brook which drain this area are impounded in two reservoirs, one on Hobbs Brook and one on Stony Brook. The Hobbs Brook Reservoir has a holding capacity of about 2 500 mil. gal., while Stony Brook Reservoir has an available capacity of slightly under 400 mil. gal. Stony Brook Reservoir, from which Cambridge takes its supply direct, is fed from Hobbs Brook Reservoir through the natural channels of the brooks between the two reservoirs.

Stony Brook Reservoir and the water filtration works are connected by 1.42 mi. of 30-in. cast-iron pipe, 0.91 mi. of 36-in. pipe and 5.2 mi. of 63-in. concrete conduit, respectively. At the lower end of this aqueduct the water passes direct by gravity to the filter plant, the excess being bypassed over a weir into Fresh Pond, which serves as a receiving reservoir. Fresh Pond drains an area of about one square mile and has an available storage capacity of about 400 mil. gal. of water.

Water Consumption. Very careful inspection of plumbing fixtures, and the prosecution of other lines of water conservation endeavor, have been instrumental, even in the absence of complete metering, in keeping the water consumption in Cambridge at a remarkably low figure. At this date the consumption averages about 100 gal. per capita. In the past twenty years the population has increased about 20 per cent and the water consumption about 27 per cent.

Quality of the Raw Water Supply. Numerous investigations of sanitary conditions on the catchment area have been made in the past twenty or more years, notably by the late Frederic P. Stearns, Prof. William T. Sedgwick and more particularly by Prof. George C. Whipple of Harvard University. The conclusions arrived at as a result of these investigations were practically the same in all cases. Professor Whipple's investigation was made in 1912–13.

The watershed is similar to many others in the potentialities offered for dangerous contamination. From a population of about 120 per sq. mi. this danger is always present. There are numerous cases where the brooks run parallel and close to highways, affording easy access to the streams of dangerous polluting matter.

It is necessary to make plain that there are strict sanitary regulations operative for safeguarding the water supply of Cambridge. The difficulties of enforcing such regulations are clearly obvious, and it has long been recognized that their strict enforcement is impossible. Furthermore, no matter how diligent and efficient a watershed patrol may be it cannot prevent the pollution of a water supply derived from surface sources, whether the catchment area be populated or not. Protection of the Cambridge supply by purchase of the entire watershed was out of the question, and in consequence the Water Board has always continued its efforts toward minimizing the pollution of the raw supply, and such efforts are even now continued although a sure safeguard against the entrance of disease germs into the distribution system of Cambridge is afforded by the filter plant at Fresh Pond. The Water Board decided, as did the engineers who investigated the problem before the speaker, that no matter how carefully the watershed is patrolled, or how little chance there is of dangerous polluting matter entering the supply, the only way in which the health and comfort of the people of Cambridge could be adequately conserved was through the medium of competent filtration, which would not only make the water hygienically pure, but free of color, offensive odor and taste, and clean.

The color of the Cambridge water supply is very similar in character and amount to that of the Passaic River water above the filter plant at Little Falls. The color is of vegetable origin, coming from decaying vegetable growths in the swampy areas on the watershed. These swampy areas have been drained to some extent by ditching, but further work along this line is highly advisable because by the swift draining of such

areas the color of the raw water could be reduced to a material degree and a substantial economy in the amount of chemical required for the removal of the color at the filter plant could be effected.

Some have claimed that the natural purification effected in the storage reservoirs is sufficient treatment to safeguard the purity of the supply. In Hobbs Brook Reservoir the salutary effect of such purification by storage is far more pronounced than in Stony Brook Reservoir, which is long and narrow and allows swift passage of the water through it, especially following heavy rains on the watershed, accompanied by a strong north wind. In this regard Professor Whipple in his report to the Water Board, dated December 17, 1913, drew pointed attention to the fact that water from the most dangerous feeder of Stony Brook conceivably could reach Fresh Pond in Cambridge within 48 hr., and possibly in a considerably shorter time than that.

A long series of analyses of the reservoir waters discloses an abundance of microörganisms, as would be expected, and it is such algæ growths which have imparted to the water supply of Cambridge the obnoxious tastes and odors of which the people have so frequently complained.

In the past all of the water supply was delivered direct into Fresh Pond, adjacent to which is located the new filter plant. From Fresh Pond the water flowed by gravity into the pump well, thereafter being forced into the distribution system and Payson Park Reservoir. The storage in Fresh Pond, which covers an area of some 170 acres, amounts to about one month's supply. The conformation of the shores of the pond encourage material purification of the water, and there is little opportunity for gross pollution from the some 9 000 persons actually resident on the territory adjacent to Fresh Pond. At the present time Fresh Pond is not utilized as a source of supply except at times when the gravity flow to the filter plant direct from the conduit is insufficient to meet the demand.

Fresh Pond is a favorable breeding ground for algæ. Algæ growths not only impart disagreeable tastes and odors to the water, but the organisms and débris resultant from such growths finding their way to the filters speedily clog them, thereby occasioning very frequent washing with the accompanying increased cost of operation. Sharp measures are always necessary during spring and summer months to check the development of algæ. Treatment with copper sulphate of the waters of Fresh Pond, as well as those of the upper reservoir, destroys the objectionable growths.

Summed up it may be said that the raw water supply of Cambridge is derived from a quite heavily populated watershed, and that the raw supply is always open to the possibilities of dangerous contamination. The water is soft, the hardness averaging about 30 parts and ranging from about 20 to 40 parts per million, of which about one-half is temporary hardness. The color of the raw supply ranges from a maximum of about 50 to a minimum of about 20 parts per million and less, and averages about 25 parts per million. The water is substantially free from high amounts of

turbidity. The bacterial content and the B. coli count are about what would be expected in a water of this character drawn from a watershed such as that described.

Purification Works. The purification plant has a capacity of 14 mil. gal. per 24 hr. and can readily be enlarged to 16 mil. gal. The raw supply is delivered to the plant by gravity through 1 480 ft. of 42-in. cast-iron pipe, leading from a weir chamber situated on the lower end of the 63-in. brick conduit which formerly fed Fresh Pond direct from Stony Brook Reservoir. At times when the gravity flow to the plant is insufficient the deficiency is made up by taking water from Fresh Pond through a 42-in. intake pipe 320 ft. long connecting with the old draft conduit, and pumping through a 30-in. pipe to the 42-in. main supply line.

The purification works are located in Kingsley Park, on city land lying between the Fitchburg Railroad and Fresh Pond, about 300 ft. northwesterly from Fresh Pond Station and 200 ft. from Fresh Pond. The purification works cover an area of about 1.6 acres. The plant consists of a covered coagulating sedimentation basin, 10 rapid sand filter units, filtered-water aërator, clear-water basin, sterilizing equipment, wash-water receiving basin, low-lift pumping equipment and superstructures. The main structures are chiefly reinforced concrete of flat slab and beam and slab type. The superstructure is brick and the roof is concrete.

The sedimentation basin is constructed of concrete, and is 137 ft. by 96 ft. and 16 ft. in effective depth. Its working capacity is 1.5 mil. gal., equivalent to a 2.5 hr. flowing-through period when the plant is operating at full capacity. The basin is divided into two bays of equal size by a longitudinal party wall. A distributing weir and downward baffle are provided at the inlet end. At the outlet end of the basin the water flows off over a skimming weir. Other accessories of the basin are distributing pipes for returned wash water, a sludge pump, overflow and gate chambers. The basin is separated from the clear-water basin by an earth bank 20 ft. thick which ensures freedom from any possibility of pollution of the filtered water from this source. There are 10 filter units, built monolithically of concrete, and laid out in one row with a pipe gallery and operating platform along one side. The clarified water from the sedimentation basin is applied to the filters from a concrete flume running parallel to the pipe gallery. The filter tank units are 20 ft. by 24 ft. by 9 ft. deep, and each has a filtering area of 480 sq. ft. Thus when operating at normal capacity each filter unit handles 1.4 mil. gal. per 24 hr.

The filtering medium is 27 in. in thickness overlying 9 in. of graded gravel. The buildings and filter equipment are in general conformity with customary up-to-date modern practice, although somewhat more elaborate in certain particulars than that observed in most filter plants. The city officials believed with the speaker that the hub of the intellectual universe was deserving of the best the art afforded in the line of a water-purification plant designed to protect the health and support the civic

pride of such a community. The filter floor is of the type known as the "Wheeler Bottom."

A feature of this plant, which however has been made use of in a few other places, is the idea of returning to the sedimentation basin the wash water discharged from the filters. This is effected by collecting the raw wash water as discharged in a covered concrete tank 37.5 ft. in diameter and 10 ft. deep. When filter washing commences the wash-water return pump in this basin is started, returning the wash water to the inlet end of the sedimentation basin. There is a 12-in. overflow from this basin leading to the city sewer.

The results of the use of the returned wash water are twofold, namely, encouragement of coagulation activities in the coagulating basin through the medium of the returned wash water which is heavily charged with precoagulated matters and which operate as nuclei in the formation of new flocs; and, second, in conserving to the utmost the limited water supply derivable from the restricted catchment area. The practice is also of benefit in guarding against overloading the city sewer with waste water at inopportune times.

The clear-water basin is a covered reservoir having a capacity of 4 mil. gal. It is 274 ft. by 147 ft. in plan and carries a maximum depth of water of 13 ft. when the aërator is in operation. The basin extends under the filters on one side, a filtered water conduit runs under the pipe gallery, and the basin is so arranged that it can be by-passed if necessary.

The sterilizing equipment is assembled in the head house, chlorine being applied to the aërated filtered water. An aërator consisting of sloping concrete slabs in which are set sharp baffles arranged herringbone fashion, releases free carbonic acid and offensive tastes and odors from the water.

The pumping equipment consists of one 4-mil. gal., two 6-mil. gal., and one 10-mil. gal. horizontal centrifugal pumping units to deliver raw water from Fresh Pond to the sedimentation basin when the gravity supply from Stony Brook is insufficient. There are two horizontal centrifugal pumps, each having a capacity of 1 100 gal. per min., which deliver filtered water into a wash-water storage tank for use in cleaning the filters. There are two vertical centrifugal pumps, each of a capacity of 1 700 gal. per min., which are utilized to return the used wash water to the sedimentation basin.

All pumps and chemical mixing machinery are driven by alternating-current, direct-connected motors, on a 550-volt, 3-phase, 60-cycle current.

The wash-water tank is 29 ft. in diameter and 34 ft. in height, and holds sufficient water to wash two filters in succession. Wash-water pumps start automatically to replenish the wash-water storage tank as soon as washing of a filter begins.

The superstructure is a two-story building 223 ft. by 71 ft. The wash-water tank is enclosed in a central tower. The first story of the

main building is built of concrete and the second is faced with tapestry brick with synthetic stone trim. The roof is of concrete covered with waterproof membrane. This building houses the filters, administration offices, laboratories, chemical storage, wash-water tank, pumps and all other machinery and devices.

Purification Process. The purification process is practically identical to that followed in so many other places, and needs no detailed description here. The water first enters the sedimentation basin at the entrance to which sulphate of alumina solution is added. The treated water is diverted at the entrance to the basin downward to the bottom thereof by means of a baffle, and thereafter passes slowly through the basin. The partially clarified water leaves the basin over a submerged wall which serves as a skimming weir. Thence the water flows through a 48-in. pipe to the influent flume of the filters, being admitted thereto through hydraulically-operated sluice gates on each individual filter unit. Passing the filters the water is collected by the strainer system, and passed through registering controllers which maintain a constant rate of filtration. The filtered water then flows into a flume below through tubes with trapped outlets. Leaving the flume the filtered water passes over the aërator, thereafter receiving a dose of liquid chlorine as a final step in bacterial purification. The ultimate product flows into the clear-water basin and thence by gravity to the Fresh Pond pumping station for distribution.

At times, particularly following heavy rains or thaws on the watershed, the alkalinity of the raw water falls so low as to make it necessary to add a small quantity of soda ash to the water as it flows through the 42-in. main supply line at a point about 100 ft. from the sedimentation basin. This compensates for deficient alkalinity and ensures complete decomposition of the added coagulant.

The filters are washed by passing currents of filtered water at high velocity up through the filter beds. The dirty water is collected in gutters at the top of the filters and drained off to the receiving basin whence it is returned by pumping to the inlet end of the sedimentation basin.

All valves in the filter and washing process are controlled from operating tables which are uncommonly substantial and ornate, being constructed of marble, bronze and plate glass.

The sludge which accumulates in the sedimentation basin is from time to time pumped out by means of a vertical-shaft, motor-driven centrifugal pump, having a capacity of 1 500 gal. per min. This sludge is discharged into a nearby sewer.

Cost of Construction. In numerous particulars this plant differs from others, and these facts tended to make its first cost greater than usually is the case. Kingsley Park is particularly attractive and demanded architectural features more ornate than in many places would be considered necessary. Furthermore, the Fresh Pond pumping station is operating on a 16-hr. schedule out of every 24, and this made it necessary to

provide an abnormally large clear-water basin in which to store water against a 50 per cent overdraft during the pumping period. The aërator and the wash-water receiving tank with piping connections and pumping equipment are other unusual items. The long connecting pipe lines furnish still another abnormal item of expense.

The figures in the following table furnish an analysis of the cost of these works:

COST OF CAMBRIDGE WATER FILTRATION PLANT.
(ANALYSIS FROM FINAL ESTIMATE.)

Item.	Bid Price.	Net Cost for Additions and Extra Work.	Final Estimate.	Properly Chargeable to Filter Plant.
A Pipe lines outside of masonry structures	$90 000.00	$3 733.56	$93 733.56	$25 000.00*
B Sedimentation basin, substructures of buildings and filter structures	328 000.00	35 406.05	363 406.05	271 000.00†
C Superstructures	80 000.00	3 418.61	83 418.61	83 418.61
D Filter equipment	225 900.00	207.00	225 693.00	225 693.00
E Chlorinator	1 400.00	0.00	1 400.00	1 400.00
Total	$725 300.00	$42 351.22	$767 651.22	$606 511.61

Rated capacity of filter plant	14 000 000 gal. daily
Bid price	$725 300.00
Final estimate	767 651.22
Extra work	42 351.22 (5.8 per cent)
Allocated cost of filter plant	606 511.61
Cost per mil. gal. rated capacity	43 322.26

The execution of this project, which means so much to Cambridge and gives equal promise to other Massachusetts communities, is the result of the great foresight and untiring persistence of ex-Mayor Good, Mayor Quinn, President Scully and other members of the Water Board, supported by the Common Council and citizens of the City of Cambridge. Credit for whatever commendable engineering features the works may possess is due to the combined efforts of all those connected with the work. The speaker's associate, Mr. Stevens, was in active supervisory charge of design and construction; and to the resident engineer, Mr. Fred S. Childs, great credit is due. The quality of the finished works bears eloquent testimony to the excellent work of the contractors.

The speaker has purposely avoided details in the foregoing remarks, preferring that they should be furnished by those immediately responsible for them. He therefore requests, before general discussion starts, that

* Estimated cost of all outside piping, $89 850. Figure given is for normal amount of such pipe lines.
† Estimated cost of 4 mil. gal. clear-water basin, $138 400. Allowance of $45 993.95 made for a basin of normal size.

remarks be requested from his associate, Mr. Stevens; from Mr. Smulski on the specific question of steel reinforcement; from Mr. Whipple on operating procedure, costs and results; from Superintendent Good, President Scully, and from Mayor Quinn.

Discussion.

Harold C. Stevens.* It is the purpose of this discussion to supplement Colonel Johnson's paper, as has been indicated by him, with a more detailed description of the principal elements of the Cambridge filters.

The location in Kingsley Park is favorable as to topography and proximity to a railroad station, and to the existing pumping station and its intake from Fresh Pond. The elevation of the plant was fixed within narrow limits by the elevation of the gatehouse on Stony Brook conduit, it being just possible by raising the water level in the gatehouse to send the water by gravity through the plant and to deliver it at an elevation within the suction limit of the main high-service pump.

It was necessary to deepen the pump suction well to correspond with the elevation of the bottom of the clear-water basin, and to provide special devices to control the suction lift to meet certain peculiarities of the pump. This was accomplished without seriously interfering with service to the city from the usual source.

The gravity supply is limited, and in order to provide for periods of high consumption or a temporary heavy draft to meet operating conditions at the pumping station, and to make available the storage capacity of Fresh Pond, a connection was made to the old intake whereby the raw water supply may be drawn by gravity to a pump well at the filter plant and be delivered as needed, by low-lift motor-driven centrifugal pumps to a point on the main supply line about 100 ft. from the sedimentation basin, far enough to permit soda-ash solution introduced into the main to become well mixed with the raw water before it reaches the entrance to the sedimentation basin where alum is applied. The use of soda ash is necessary during the time of year when the natural alkalinity of the water is too low for proper coagulation to take place.

Venturi meters are provided on the gravity supply line and on the force main of the pumped supply.

The present water supply from Stony Brook conduit is a little less than the nominal capacity of the filters and a little more than the city needs, but it is possible by cleaning the cast-iron portion of the conduit to increase its flow about 25 per cent which is sufficient to avoid the use of low-lift pumps almost entirely.

Plate I shows a general plan of the filter plant.

* Consulting Engineer, New York.

Sedimentation Basin. Water enters at the bottom of a chamber at one end through a hydraulically-operated shutter valve, float controlled, for maintaining a practically constant water level in the sedimentation basin. The coagulant is applied at this point through a perforated grid. The water rises in the chamber, passes into channels running across the end of each compartment of the sedimentation basin, flows over the edge of the channels, is turned downward by a baffle and thence flows through the basin. Either or both compartments of the basin may be used. The inlet channels have openings in the bottom through which part of the flow passes and carries away any sediment that otherwise would accumulate in the channels. Channels across the outlet end receive water over their edges from the surface of the settled water, and deliver into an effluent chamber and thence through a pipe to the filter influent flume.

A chamber at the inlet end of the sedimentation basin receives returned waste wash water, and distributes it across the basin through perforated pipes near the bottom and just beyond the baffle. At the outlet end is a chamber containing a motor-driven centrifugal sludge pump, and an overflow chamber discharging through a 12-in. pipe into Fresh Pond. This pipe also serves for draining the basin down to pond level in connection with cleaning operations. A system of piping, connected with the city force main is provided for flushing the basin with hose.

Filters. The ten filters are arranged in a single row with operating floor and pipe gallery alongside. Foundations for six future filters are provided so that extension can be made without seriously interfering with the operation of the plant. A concrete influent flume supplies all filters through independent valved connections discharging into the waste-water compartment across the front of each filter, whence the water flows through the gutter openings and spreads gently over the sand beds, filters through the sand into a collecting system underneath and thence through piping and rate controllers to the clear-water flume below.

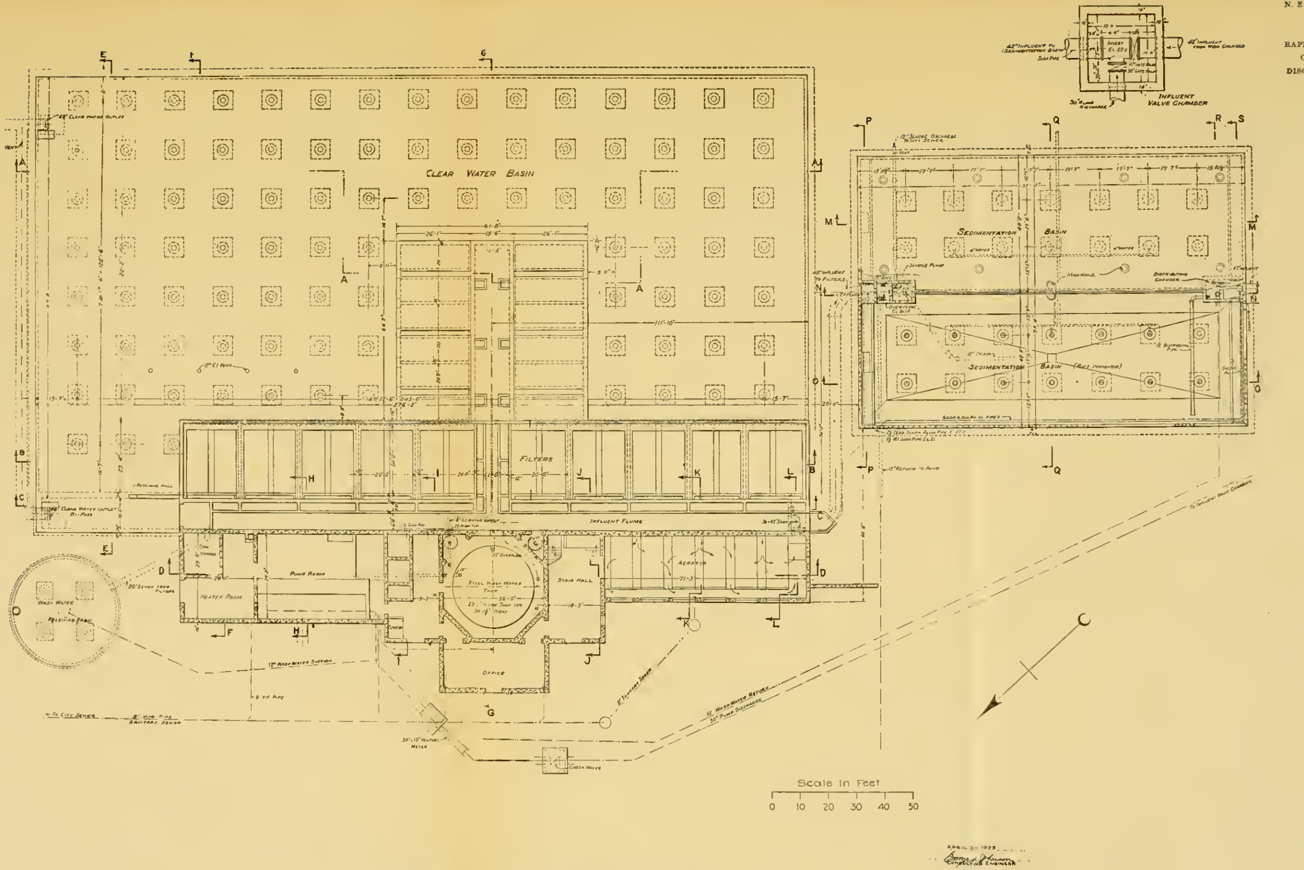
The clear-water flume may deliver over the aërator to the clear-water basin, the usual way, or it may without aëration deliver either to the clear-water basin or direct to the pumping station.

Chlorine is applied at the entrance to the clear-water basin.

All valves ordinarily used are hydraulically operated and are controlled in the usual way from operating tables placed on the floor above, these tables also carrying the indicating and recording gages appurtenant to each filter.

Along with the operating tables are provided a wash-water meter register, a depth gage for the clear-water basin, and a sampling table where samples of the water in its various stages of treatment may be drawn for analysis. In the pipe gallery are cocks for taking samples of filtered water from each individual filter.

Clear-Water Basin. The clear-water basin has a capacity of 4 mil. gal., including the clear-water flume. This is exceptionally large in order to



GENERAL PLAN OF FILTRATION PLANT.

adapt the operation of the filter plant to the main high-service pump which discharges approximately at the rate of 20 mil. gal. per 24 hr., making it necessary ordinarily to deliver the day's supply within a period of 16 hr.

The type of concrete reinforcement adopted for the roof and floor of this basin, and similarly for the sedimentation basin is of particular interest, and a description of it will be included in another discussion covering the methods of reinforcement used in the Cambridge filter plant.

Washing. Wash water is delivered from a steel tank 29 ft. in diameter and 34 ft. high, through a main with valved connections into the effluent pipe of each filter, passes reversely through the collecting system and upward through the filter at a rate of about 15 gal. per sq. ft. per min., loosening the sand and carrying off the accumulated muddy matter.

The dirty water runs through the gutters to the waste compartment at the end of each filter and thence through a drain to the wash-water receiving basin. From this basin the dirty water is returned to the sedimentation basin by pumps which start automatically as soon as the receiving basin begins to fill.

The receiving basin is an unusual feature installed for the purposes of saving water and of aiding coagulation, as has been more fully stated by Colonel Johnson.

The wash-water tank contains enough water for two successive washes and is replenished by small motor-driven pumps one or both of which start automatically with the draft on the tank. A connection with the city force main may also be used to fill the tank in emergency. Wash water delivered by the pumps is measured by a Venturi meter.

Plate II and III show various sections of the filters, clear-water basin, aërator, etc. Plate IV shows various sections of the sedimentation basin.

Plate V shows details of a filter unit and the arrangement of pipe, valves, and other appurtenances.

The collecting system of the filters is worthy of comment. It is known as the Wheeler bottom. It serves to collect and deliver the filtered water, but its more important function is the proper distribution of wash water beneath the filtering material.

It consists of a central duct through the middle of the filter with closely spaced lateral ducts, all formed in concrete.

Each lateral has a series of openings, shaped like inverted pyramids, in which are placed cement balls of varying size, a large one at the bottom, four smaller ones above it, and nine, still smaller, in the top layer. These balls spread out the entering wash water and deliver it gently and evenly into the overlying gravel, thus causing a very uniform upward flow with no tendency for the water to bore through the sand and gravel, and leave unwashed spaces between openings.

Aërator. The aërator consists merely of cast-iron plates studded with short baffles 6 in. long and 4 in. high set diagonally. The plates lie on a slope of 3 ft. on 8 ft. Their total area is 923 sq. ft.

The water flowing down over these plates is thoroughly splashed and turned over so that there results an effective release of carbonic acid and thorough contact with the air with consequent deodorization. Three feet of head is necessarily lost through the operation of the aërator.

Chlorinator. A separate room is provided for chlorinating equipment and storage of chlorine, with no interior connection to the rest of the building except a double door opening to the filter-operating floor. The equipment consists of a Wallace and Tiernan pedestal type chlorinator with accessories.

The chlorine is applied through a rubber tube at the point where the water passes from the aërator to the clear-water basin.

Chemical Equipment. Chemicals are dissolved in concrete tanks provided with motor-driven mixing devices. The dissolving of chemical is accomplished by placing it on a grating in a compartment at the top of the tank and spraying upon it the water used to fill the tank. The alum solution is passed through a small filter and delivered by a little pump to orifice tanks at sufficient elevation to permit gravity flow to the point of application at the entrance to the sedimentation basin. The soda solution is similarly measured through orifice tanks and then forced by a water jet eductor through the delivery pipe.

Ample storage space, with elevator, provides for receiving chemicals in carload lots.

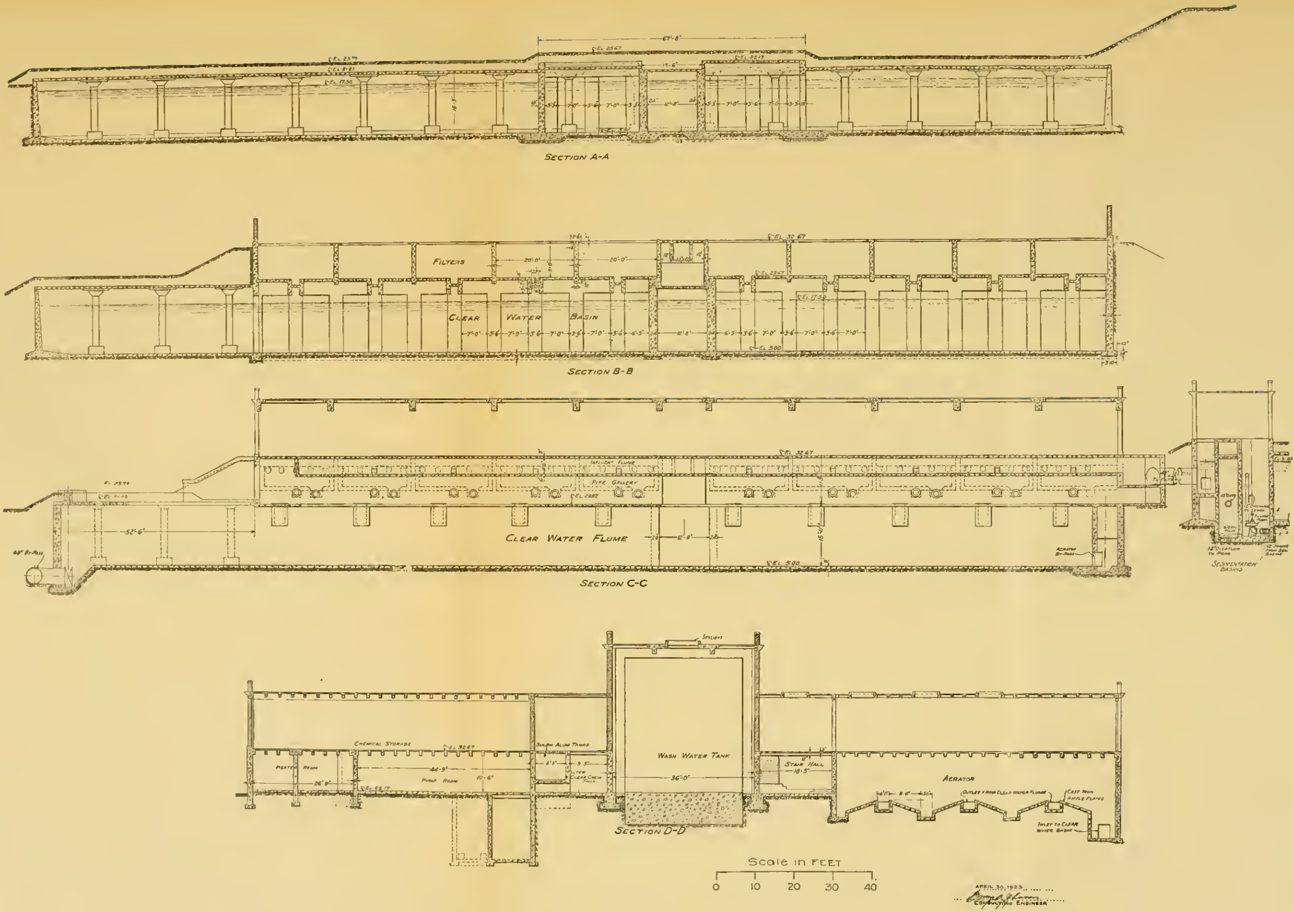
Laboratories. A well-equipped laboratory is an essential factor in a properly-conducted filter plant. Three rooms are provided for this purpose and they have been furnished with complete facilities and the best of apparatus.

The Cambridge filter plant represents the best filter practice and is of high-class construction. The photographs herewith reproduced give a clear idea of the character of the plant. The city of Cambridge is assured of constantly pure water supply and conservation of its past development, all at a reasonable cost, adequate for many years, and capable of extension when more water is required.

TIMOTHY W. GOOD.* The people of Cambridge are indebted to Col. George A. Johnson for furnishing the Water Board with what is considered by experts to be the finest mechanical filter plant in this country. One must, however, see the plant in operation to appreciate fully his work.

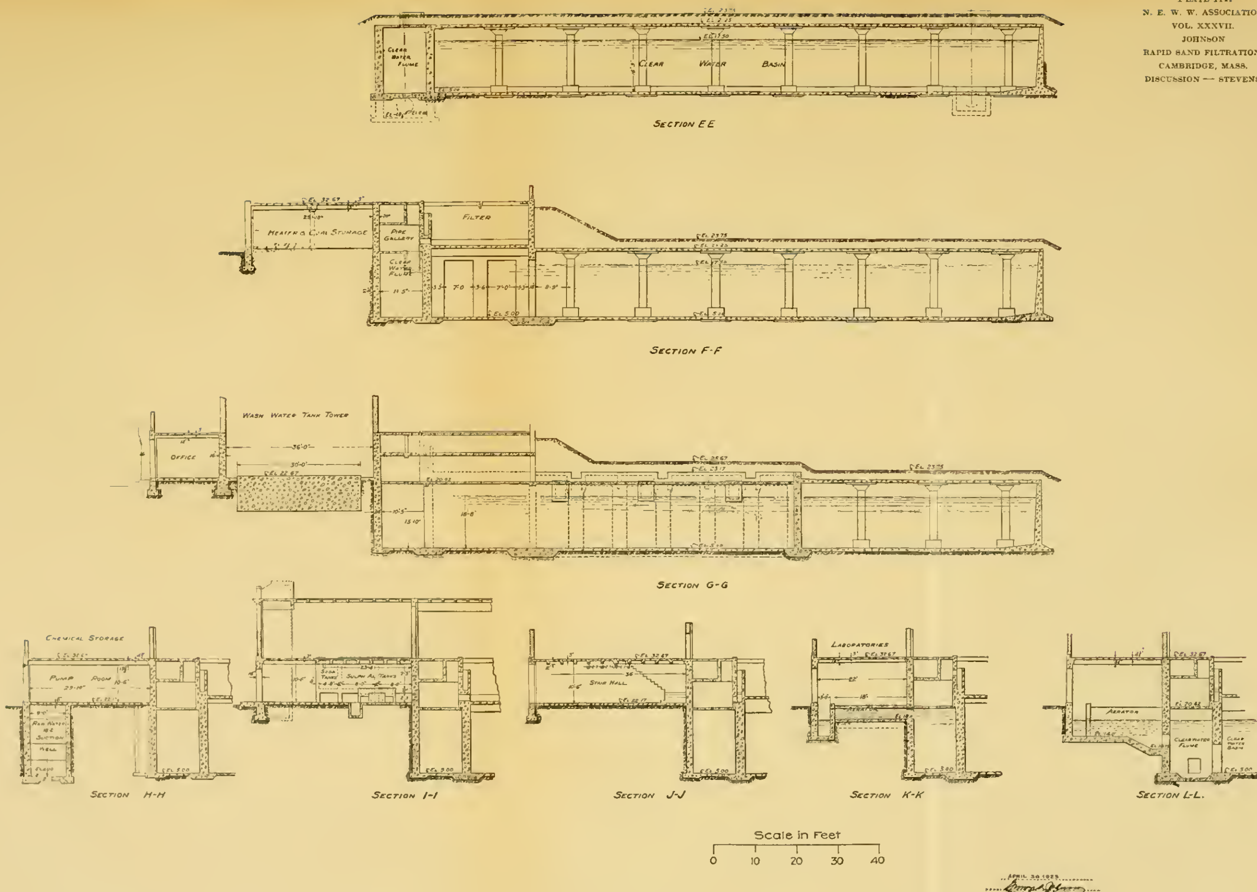
His method of handling the many intricate problems, the rapid completion of the plant, and the wonderful results obtained, have earned for him the everlasting gratitude of the Mayor, Water Board, and the citizens of Cambridge. I regret very much that Mr. Melville C. Whipple, our consulting chemist, is not present, but pressure of work at Harvard University prevented his attending. I will, however, endeavor to give you an idea of the chemical operation as well as the practical operation of the plant.

* Superintendent, Water Works, Cambridge, Mass.



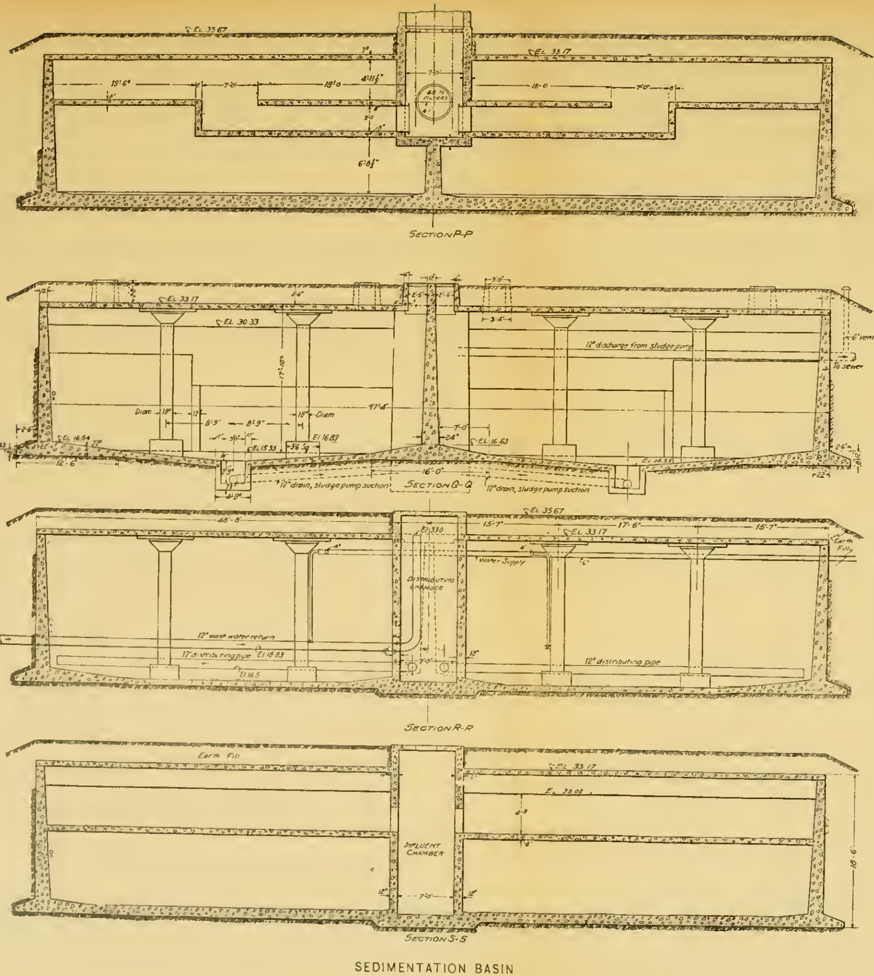
FILTERS, CLEAR-WATER BASIN, ETC. — SECTIONS.

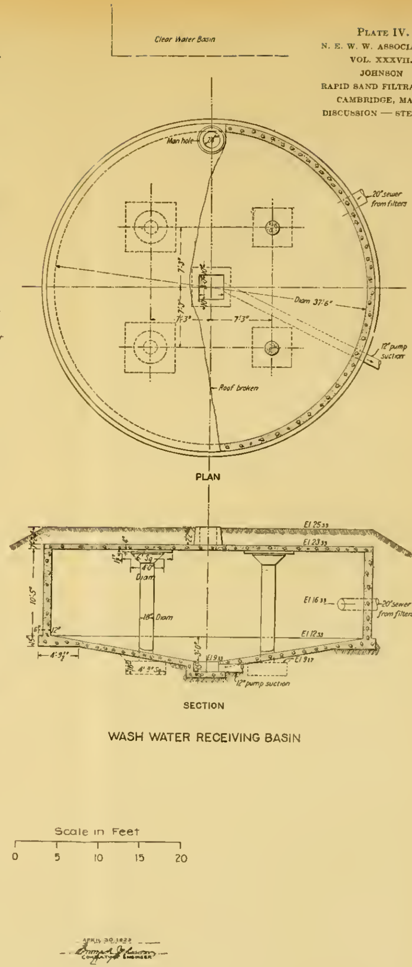
Plate III.
N. E. W. W. Association.
Vol. XXXVII.
Johnson
Rapid Sand Filtration,
Cambridge, Mass.
Discussion — Stevens.



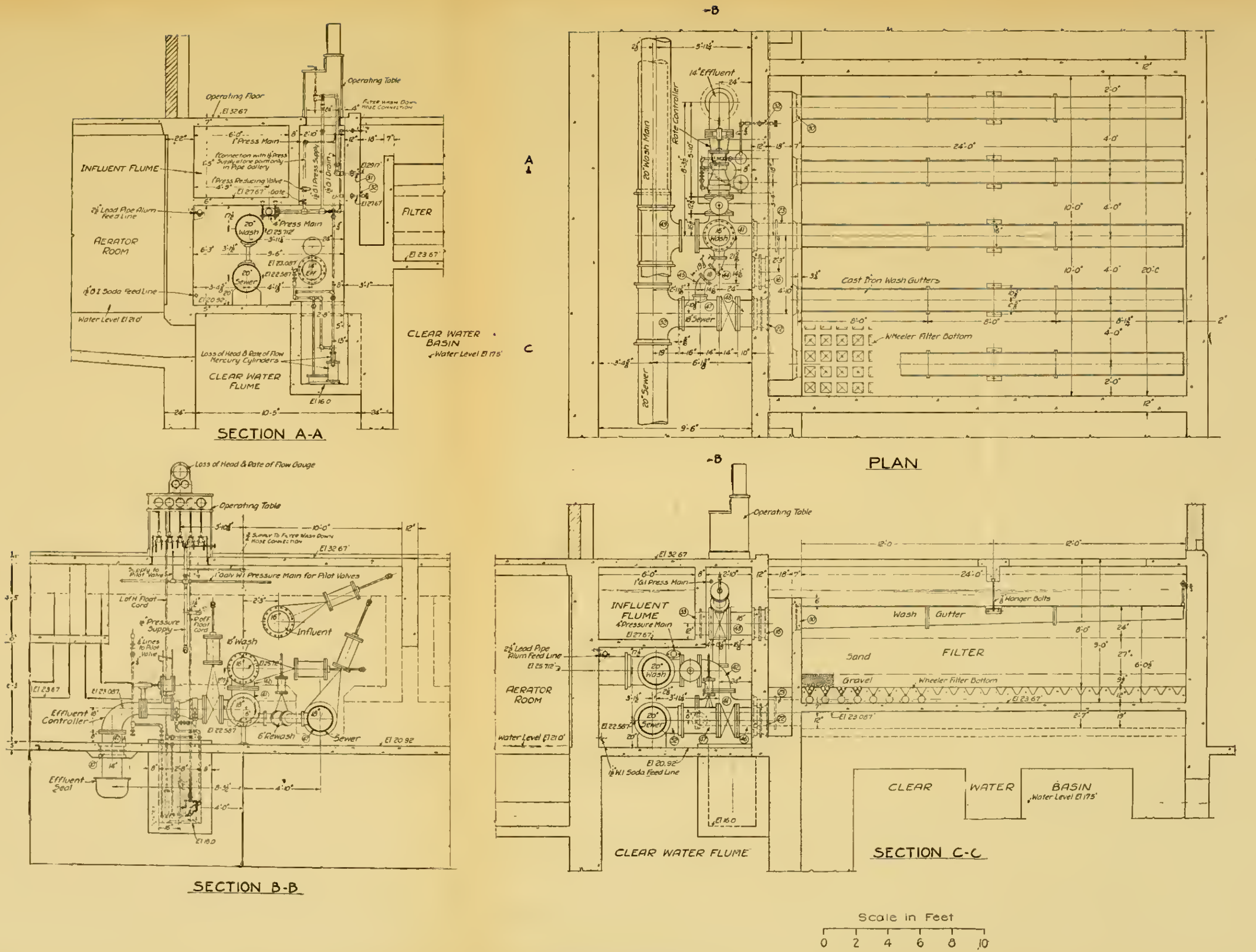
FILTERS, CLEAR-WATER BASIN, ETC. — SECTIONS.

Plate IV.
N. E. W. W. Association.
Vol. XXXVII.
Johnson
Rapid Sand Filtration,
Cambridge, Mass.
Discussion — Stevens.





SEDIMENTATION BASIN AND WASH-WATER RECEIVING BASIN.



DETAILS OF FILTER UNITS.

Rapid sand, or, as it is oftentimes called, mechanical filtration, differs from slow sand filtration in three essential particulars. In the first place, water is passed through the sand at a rate some thirty times faster than in slow sand filtration. Second, entirely different means are used for cleaning the sand when the filters become clogged. The flow of water is reversed, the sand put in suspension and the grains rub against each other until they are clean. In the slow sand process the upper layer of sand, usually about one inch, is removed by scraping and the sand is washed in special apparatus. It is not returned to the bed until successive scrapings have greatly reduced the depth of sand. The third essential difference in the two processes arises from the use of a coagulating chemical, which is added to the water before filtration. This removes the largest portion of impurities, both living and inert, in a settling basin, and so makes possible in the rapid method the use of much higher rates of filtration. Coagulating chemicals are not ordinarily employed previous to slow sand filtration.

Description of the Coagulation Process. Coagulation, in water treatment, implies the natural assembling of minute particles of precipitate into relatively large flocs, which incidentally entrain particles of clay, of organic and coloring matter, and of living organisms, such as the bacteria and algæ. The process accomplishes the same result as the addition of white of egg to coffee, which is often added to clarify it. The egg white there coagulates, forming large particles which readily settle. These particles in the process of forming include and drag down the small particles which give the coffee a muddy appearance.

For purposes of water treatment the coagulating substance must be one which will form a coarse precipitate and settle readily. Such a substance is aluminum sulphate, sometimes called filter alum. It has weak acid properties. A solution of this substance is added to the water just before it enters a settling, or sedimentation basin. Being weakly acid, it combines with the alkaline salts naturally present in the water. These are bicarbonates of lime (calcium) and magnesium. The result of this combination is the formation of an insoluble compound, aluminum hydroxide. The latter first forms in very fine particles. These gradually come together to form visible masses of a sticky, coarse nature which settle readily. In the formation and settling, bacteria, algæ, and the minute particles giving rise to color and to a "roily" appearance are caught in the precipitate of aluminum hydroxide and removed from the water. The time required for settlement will vary from two to four hours and this period is obtained by the passage of the treated water through the settling basin. The amount of aluminum sulphate used will vary with the temperature and the quality of the raw water and will probably be between 200 and 215 lb. per mil. gal., that is, between 1.4 and 1.5 grains per gal.

All of the precipitate formed in the basin does not settle out there. Some of it passes on in the water to the filters, where it is caught on the

surface of the sand and aids in building up a mat which greatly increases the efficiency of the filtering process. When this mat becomes so thick that the passage of water is interfered with, the filter has to be washed. The nature of the water, and the matter in suspension, is different from that found in any other part of this country. The floc formed by adding alum is light and of a sticky nature, more especially in warm weather, forming a much denser mat on the top of the filter bed than could be removed by ordinary washing. This we overcame by increasing our rate to 18 gal. per sq. ft. per min. The settling basin must also be cleaned periodically. This is indicated by the time when precipitate is carried out of it to the filters in such quantity that the latter have to be washed too frequently.

The Use of Soda. After treating the raw water with aluminum sulphate, there must always remain an excess of alkaline salts, "alkalinity" as it is called, in order that no aluminum sulphate may be carried into the mains. The amount of natural lime salts may at times be insufficient to assure this. Laboratory examinations will indicate the condition. Then it will be necessary to add artificial alkalinity in an amount equivalent to the deficiency of natural alkalinity. The substance used for the purpose is sodium carbonate, or washing soda, which is introduced to the raw water as a solution. The apparatus for doing this, and for adding the solution of aluminum sulphate, is accurately controlled and the exact amounts are checked by laboratory analyses. Neither of these substances is added in an amount which can be tasted or be harmful. Furthermore, the aluminum sulphate is precipitated from the water, as above described, before it is filtered. It may be necessary to add soda only a few weeks each year and possibly not at all.

Other Substances Formed in the Coagulation Process. When part of the alkaline lime and magnesium salts are neutralized by the aluminum sulphate with the formation of the precipitate of aluminum hydroxide, they are converted into sulphate of lime and magnesium, respectively. These remain in solution. The total hardness is unchanged in amount, but its character is changed.

The reaction of the coagulating process also gives rise to the formation of carbon dioxide, or carbonic acid, the substance which is used to charge soda water. Some of this gas is present in the natural raw water. The amount in the filtered water will be doubled. It is a fact known to chemical science that carbonic acid increases the ability of water to corrode metal pipes. It also promotes the growth of algæ in uncovered reservoirs. For these reasons an aërator has been provided to take out part of the gas, also to remove odors. When water containing carbonic acid and substances causing odors is brought into intimate contact with the air there is a tendency for these to escape from the water. The aërator receives the water after filtration.

The Disinfection of Cambridge Water. Disinfection is primarily

employed for the purpose of destroying disease bacteria which find their way to natural waters. The germs of typhoid fever, cholera, dysentery, and diarrhœa may occur from time to time. They do not multiply but tend to decrease in number. The process also destroys many harmless forms of water bacteria and certain other types which originate from objectionable sources but are not disease-producing forms. They are indicators of possible danger in that disease bacteria may accompany them. Such a type is Bacterium coli.

A large percentage of all forms of bacteria are removed by the process of coagulation and settling. The number is further decreased by filtration. To guard against fluctuations or irregularities in the quality of the filtered water, disinfection is employed as a finishing process before the water leaves the plant. It is accomplished by the addition of a solution of chlorine gas. The amount required does not exceed 3 lb. of chlorine per mil. gal., and is very accurately measured and controlled by the Wallace and Tiernan Vacuum Feed Chlorinator. Of this amount practically none can reach the mains of the city because the chlorine is neutralized by the bacteria and by the small amount of organic matter in the water. Ordinarily no chlorine will be found by test 30 min. after it is added. Chlorine has never been considered injurious in the amounts in which it is used in water disinfection. It is intended that no chlorine will be present in the water as it comes to the consumer's tap.

The water will not be sterile after chlorine treatment. There is nothing to be gained in an attempt to destroy all the common, harmless species of bacteria. What the processes of coagulation, filtration, and disinfection are designed to accomplish is the elimination of "objectionable aliens," such as Bacterium coli. If these are destroyed, we may then assume that specific disease organisms have also been removed.

The filter plant was placed in operation April 14, of this year, and our aim was to give the maximum of efficiency with a minimum of cost, both of which I am proud to say we have accomplished. We are operating with a chemist, 5 filter operators and 1 electrician, making a total of 7 men to operate the plant, each man working 8 hr. per shift, changing every 5 days. We filter approximately 13 mil. gal. of water every 24 hr., while our pumping is completed within a period of 15 hr. The return of wash water is not a detriment to good coagulation as the efficiency of coagulation basin is from 60 per cent to 70 per cent. While our gravity supply delivers 12 to 13 mil. gal. per day, there are times when our auxillary pumps lift from 1 to 4 mil. gal. from Fresh Pond, thus insuring capacity at all times. I might state here that returning the wash water to the sedimentation basin has conserved 87 mil. gal. of water that would otherwise have passed into the sewer. We have found that the best sand for the filter beds could be secured a short distance from Cambridge, namely Newburyport Plum Island sand, and the best results in length of run, removal of bacteria, color and turbidity were obtained from filter beds having effective size of

0.40 to 0.42 mm. The color of our raw water averages 30 parts per million, the turbidity 3 parts per million. After the water is filtered, color and turbidity are practically 0. Our removal of bacteria is usually 100 per cent. With iron removed to within .05 parts per million, with all gases, growth, and color entirely removed, we take great pride in delivering water to the consumer practically perfect for drinking, household, and industrial purposes at a cost of 10 cents per 100 cu. ft. Our operating costs at plant are not in excess of $8.00 per mil. gal. delivered at pumping station.

Now, gentlemen, in behalf of the Mayor and the Water Board of Cambridge, I want to extend to the President and members of your Association an invitation to hold one of your fall meetings, as guests of the city of Cambridge, at the filter plant, where we assure you that every courtesy will be shown you, and we will give you an opportunity to view what we consider one of the finest filter plants in the world, and one of the best examples of a municipal building that stands in the United States.

Edward Smulski.* This discussion supplements Colonel Johnson's paper so far as structural features of the plant are concerned.

Roof and Bottom of Basins. The roof and bottom of the sedimentation basin, wash-water basin and of a major part of the fresh-water basin are of reinforced-concrete flat-slab construction. The arrangement of panels and the spacing of columns are evident from the plan of the clear-water and sedimentation basins shown in Plate I.

The columns are spaced 17 ft. 6 in. on centers. The construction of the roof consists of a slab supported by columns with enlarged capital. At the column capital the slab is thickened by the introduction of a square drop panel. The bottom of the basin is of similar design. The capital however is replaced by a concrete block placed above the slab. The drop panel is placed under the slab to simplify the construction and to avoid form work. The general features of the design may be seen in the sections through the basins. Section FF in Plate III shows a section through the clear-water basin and Plate IV shows sections through the sedimentation basin.

The roof is designed to carry in addition to the weight of the slab a load of 340 lb. per sq. ft. The bottom is designed for an upward pressure equal to the unit load on the roof.

An interesting feature of the design is the flat-slab reinforcement. This is arranged according to the S. M. I. or Smulski system, which is distinguished by the use of a combination of rings and radial bars. By this arrangement considerable economy in steel is obtained. In ordinary cases at least 25 per cent of steel is saved without reducing the strength of the construction.

Figure 4 shows the arrangement of steel in detail and represents an interior and exterior panel of the roof. The steel indicated by heavy lines is placed near the top of the slab while the steel shown by light lines is near the bottom.

* Consulting Engineer, New York City.

In general the reinforcement consists of four types of units designated by letters A, B, C, and T. Units A and B are placed near the bottom of the slab and serve to resist the positive bending moment. Units C and T are placed near the top of the slab and resist the negative bending moment.

The composition of the various units is evident from the illustration. Unit A, which is placed between columns, consists of 4 concentric rings and 3 bars, one of which is bent up to the top of the slab at both ends and carried across the column into the adjoining panel. Unit B, placed in the

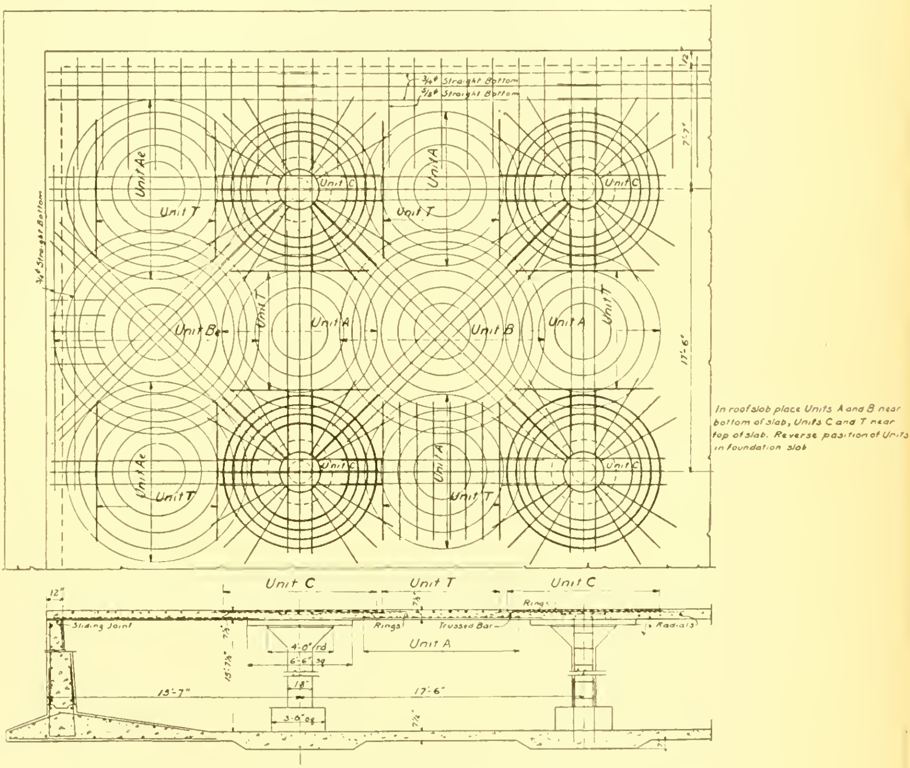


FIG. 4. TYPICAL REINFORCEMENT OF ROOF OF BASINS.

center of the panel, consists of 6 concentric rings and diagonal bars. A part of the diagonals are bent up and carried to the column where they are anchored.

Unit C, placed at the column, consists of rings and radials. Some of the radials do not extend across the column but are hooked to a ring placed within the column head. The negative reinforcement at the column is supplemented by the bent bars from Units A and B.

Unit T, placed across Unit A, consists of straight bars.

It should be noted that the rings of the various units overlap, forming a continuous mat of reinforcement. At the column the large concentration

of small bars, usual in other systems, is avoided. The bars there are far apart so that the concrete can be poured without difficulty.

Action of S. M. I. Reinforcement. The action of the reinforcement may be understood by considering the deflection of the slab. When loaded, the slab in a general way assumes the shape of an umbrella at the column and the shape of a saucer in the central part. The umbrella-shaped part of the slab acts like a circumferential cantilever loaded over its area and also along its circumference by the load transmitted to it by the rest of the slab. The circumferential cantilever is subjected to negative bending moment. The particles near the upper part of the slab elongate and are therefore subjected to tensile stresses. Reinforcement must be placed near the top of the slab. It is clear that the stresses will act on all sides in circumferential and radial directions. The most effective reinforcement accordingly is placed in circumferential and radial directions. The rings act like hoops on the barrel. They prevent the concrete within from spreading and thereby keep the construction intact.

The central portion of the slab, which assumes the shape of a saucer is subjected to tensile stresses at the lower portion of the slab. The steel is placed at the bottom and the action of rings is similar to that at the column and the hooping action is equally effective.

Bending of Rings. The bending of rings is a very simple process. An ordinary tire bender may be used for the purpose. This consists of three rollers, two of which are at the bottom and one at the top. One of the bottom rollers and the top roller are connected by gears with the driving shaft. The other roller is free. Its position with respect to the other two rollers may be varied by moving it up or down. The position of the free roller determines the size of the ring. The tire bender is usually run by power.

The bars to be bent are first cut to lengths equal to the circumference of the ring plus the length of the lap. The bars are passed through the bender, the ends are then brought together and properly lapped and wired. This bending is simpler than the two double bends required in rectilinear arrangement.

Flat Slab vs. Groined Arches. The principal advantage of the reinforced-concrete-slab type over groined arches is that the reinforced-concrete construction is stable under all conditions. The required dimensions for the roof and bottom can be computed with sufficient accuracy. The factor of safety depends upon the assumption made by the designer and he can get as strong a structure as he desires without waste of material. Each part of the slab depends for its stability only upon the construction immediately adjacent. The weakness in any part is confined to the part in question. This means that if for any reason a portion of the slab should fail, such failure will not cause the collapse of the whole structure.

With groined-arch construction the stability of the arches does not depend upon the strength of the arches but upon the strength of the walls. If the walls yield the whole structure fails. No section is stable by itself.

One section supports the other. Failure of one arch causes failure of the whole row of arches. There is no rational method of designing the arches. The designer cannot be sure of the factor of safety. Even excessive thickness of the arches will not insure safety of the construction because yielding of walls would destroy the arches irrespective of the dimensions.

Walls. The side walls of the basins are of the inverted T type. The roof rests on the wall but it is not connected with it. A sliding joint is provided between the wall and the roof so as to relieve the heavy stresses in the wall that otherwise would be caused by expansion and contraction of the roof. The base of the wall, however, is built monolithically with the bottom of the basin.

The walls are designed for two conditions. First for earth pressure considering the basin empty; Second for water pressure with the basin full. In the latter case it is assumed that one-half of the water pressure is resisted by the passive earth pressure. It was not considered advisable to assume that the earth would resist the full water pressure.

The design of the wall and the arrangement of reinforcement are indicated in Figure 4.

Filters. Section BB in Plate II shows the filters, which are supported over and along one side of the clear-water basin. There are ten filters placed in a row, in two groups of five each. Each filter is in the form of a box enclosed on four sides and on the bottom and supported over the clear-water basin. The bottom of the filter forms a part of the roof of the basin.

Figure 5 shows details of the filter construction.

The bottom of the filters is of beam and slab design. The arrangement of beams is evident from the cross section. Beams and slabs are designed to carry the heavy filter load including water.

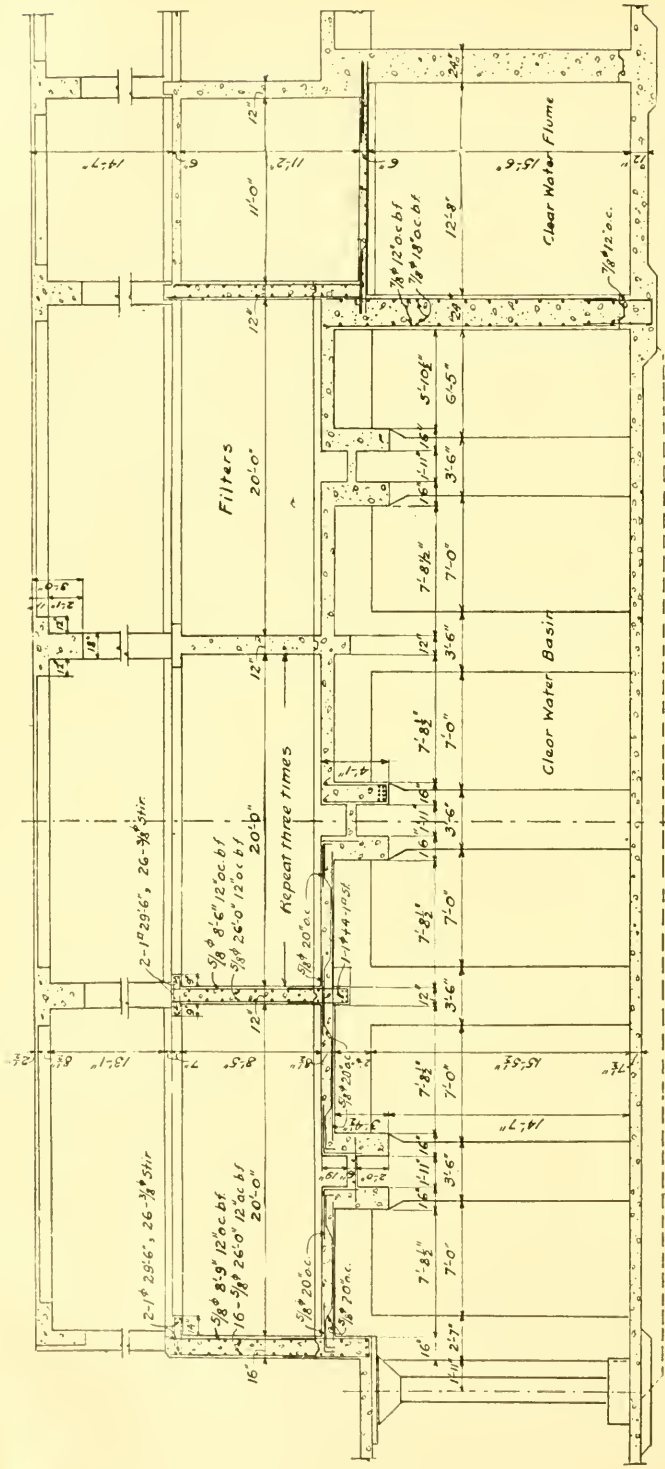
The walls of the boxes are designed to resist full water pressure, considering the adjoining filter empty.

The filter bottom rests on special columns in the clear-water basin and on the wall in the clear-water flume.

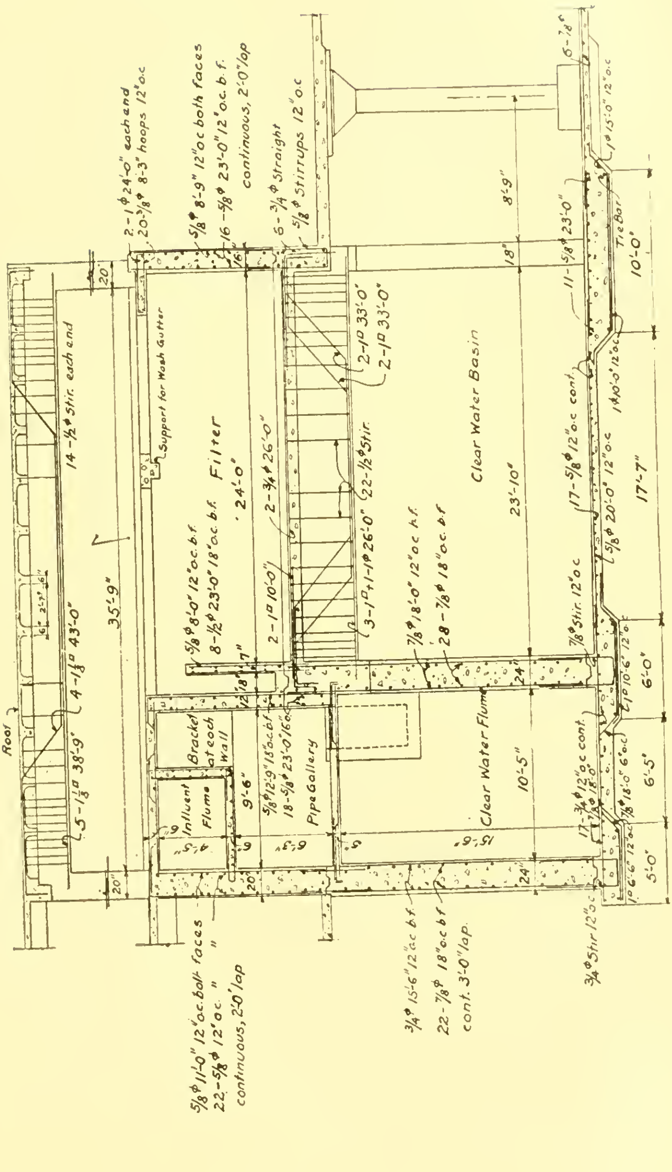
The pressure under the footings carrying the filters is considerably more than under other footings of the basin. It was anticipated that there would be more settlement under the filter than elsewhere, and there is provision in the reinforcement of the roof and the bottom for the reverse bending due to such settlement.

Temperature Reinforcement. To make the structure as water-tight as possible, all parts of the structure are provided with proper amount of temperature steel, and cracking at the juncture of the various members is avoided by proper negative moment reinforcement.

Superstructure. The superstructure floors and roof are of long span joist construction. This consists of narrow joists spaced 27 in. in the clear and connected by a thin slab. This construction was obtained by the use



LONGITUDINAL SECTION



CROSS SECTION

Fig. 5. Reinforcement of Filters.

of steel forms or pans. Figure 5 shows the arrangement of the joists in the roof over the filters.

The joists are carried by long span girders. The design of the girder over the filters is shown in elevation and section. The T flange of the beam is obtained by making the slab adjacent to the beams of a thickness equal to the depth of the joists.

Mr. Lewis I. Birdsall.* I would like to ask Colonel Johnson if he considered, in returning the wash water to the receiving basin, the putting in of a weir and permitting the heavier solids of the wash water to settle out, weiring over the clear water and pumping that back? I ask that question because we considered it at Minneapolis in connection with the plant there, having taken up with the City Engineer the building of a wash-water receiving basin where it would be very easy to run the wash water. We, however, would have had to separate our sanitary sewage from the wash water. I take it for granted that you did that in this case in designing it, so that the sewage from the toilets did not go into that effluent.

Colonel Johnson. That is so. The sanitary sewage from the toilets in the filter plant goes directly into a near-by sewer. We made no attempt to settle out the heavier solids from the wash water before it was returned to the sedimentation basin, for the reason that the city sewer, into which the wash water is discharged, is restricted in size and somewhat flat in spots and we were afraid of deposits. Consequently, we endeavored to keep all suspended matters in the return wash water in suspension and took them all to the sedimentation basin because we thought we could take care of them better there than we could otherwise.

Mr. W. C. Hawley.† I was interested in this proposition of the use of the returned wash water. When we built our plant — the Pennsylvania Water Company, in Wilkes-Barre, Penn., in 1909 or 1910 — we introduced the same feature there. However, the wash water is allowed to settle for a period of about five or six hours, and then returned to the sedimentation basin. We found by analysis that the wash water after settling was a better water than the raw water from the pumping station. I figured that after we had lifted that water some 600 ft. in the air we could not afford to let it run downhill again, and we have been able to operate our plant with a use of about one-tenth of one per cent of water for washing.

Mr. F. H. Hayes.‡ May I ask, Colonel Johnson, why, in the first starting of the filter at Cambridge, the water was so blue?

Colonel Johnson. Why, I think it might have seemed blue because it previously had been so yellow. I don't know of any other explanation.

Mr. Hayes. I might say that what brought it to our attention was that in our washbowl we noticed, when you first put the filter plant in use,

* Of the General Chemical Company, Chicago, Ill.

† Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

‡ Of Hayes Pump and Machinery Company, Boston, Mass.

before there was any notice of its being in operation, there was a blue streak, and until about three or four weeks ago it was there. Now it is getting to be a little brown.

Colonel Johnson. I am sure I do not know. The reason, perhaps, it is getting a little brown now, is because of some changes at the pumping station which have necessitated the closing down temporarily of the filter plant, until the necessary changes are made.

Mr. Caleb M. Saville.* Colonel Johnson has courteously referred several times to our good-natured discussion of the merits of slow and rapid sand filtration plants as exemplified in those recently constructed at Hartford, Conn., and Cambridge, Mass.

At the outset it may, perhaps, be pertinent to reiterate what is almost axiomatic in water-supply filtration work, viz., that while first cost of the slow sand type of filter is usually in excess of that of the rapid sand type, yet when it comes to operation, with our New England waters at any rate, the capitalized cost of operation and maintenance of the latter, including labor, materials and power, compared on the basis of unit volume delivered, often more than makes up for the lower first cost of the rapid plant, including both interest and depreciation.

Colonel Johnson's paper, including those of his colleagues, is one of the most complete descriptions of an up-to-date rapid sand filtration plant that it has been my privilege to listen to, and it is to such papers as his that this Association owes the enviable place it holds in water-works affairs and places the contents of its journals in the forefront of practical water-works literature.

The paper is a very clear exposition of what has been done in Cambridge to give the people a really good water supply. I have had the privilege of inspecting the Cambridge filtration plant, and very gladly testify to the excellent appearance of the buildings, both inside and out, to its apparent convenience for operation, and its general businesslike atmosphere. The buildings are attractive without being ornate, and in keeping both with their surroundings and their place in the municipal planning of a city of the importance of Cambridge.

At this time it is well to pause for remark that engineers too often overlook the esthetic in the search for the utilitarian. The great example for all time of the careful blending of the architecturally beautiful with efficiency in use and operation is found par excellence in the development of the Metropolitan Water Works under that master of water-works engineering, the late Mr. Frederic P. Stearns. The nearby imposing buildings of this system for housing pumps and other appurtenances at Chestnut Hill Reservoir forbids any rough building in this vicinity for similar purposes just suitable for shedding the snow and rain. The taxpayers to-day are demanding that something be shown above ground for the money

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

expended, and with present human nature no amount of agreeable sanitary water manufactured out of sight can quite compare with that which comes, as it were, in an attractive package.

Right here, however, is where perhaps Colonel Johnson and I part company, or maybe each of us goes to his own side of the same street for a little while without the least prejudice to each other's viewpoint in looking for the best. The whole nub of the matter is: What is the best method of filtration for individual conditions? What may have been the governing factors in choosing rapid sand filtration for Cambridge I do not know, but for Hartford I can say that there was much difference of opinion at the outset as to the best method of filtration for Hartford water, and while the advice of some of the best known experts in this line in the country was sought, even that was divided between rapid and slow sand methods. However, from the operating conditions that have existed since the plant was put in commission, I am very frank to say that I am glad that the choice of slow sand filtration was made, and if the question was now to be decided with past experience I should be more confident than before that the slow sand type of filtration was the proper one for Hartford's water.

The matter of discussion which Colonel Johnson has referred to was really brought upon him by himself. He took occasion some time ago to write an article in one of the scientific papers which I saw giving some figures of the cost of the Cambridge work. Apparently he gave them in a tentative way — did not go into details, but just some rough approximations. I took them for what they said, and made comparisons, and since he has been permitted to revise his figures perhaps I also may revise mine at some time.

The two plants, the Hartford slow sand plant and the Cambridge rapid sand plant, are interesting as having both been built at about the same time and under similar conditions of labor and material costs. Otherwise from that there are some things about both plants which make it really impracticable to compare them fully. For instance, Cambridge has a reservoir storage capacity of something like 2 500 000 000 gal. in round numbers. Hartford has a storage in the neighborhood of 10 000 000. There is a capacity in one of its new reservoirs of 8 000 000 000 gal., which can be called on for decolorization by storage, and 2 000 000 000 more are in other reservoirs — in three other reservoirs. If at any time the large reservoir gets into shape from algæ growth, or something of that kind, so that it is not easily handled with slow sand filters, it is a very simple matter to turn to the other reservoirs and use one or all while the others are being put in condition.

Another thing Colonel Johnson spoke of was a maximum color in the neighborhood of 50, with an average of perhaps 25. Hartford's color has run in the neighborhood of 22 or 23 average for raw water, but has never gone much above 32 or possibly 33. With present reservoir operations it is possible to get raw water about all of the time of color seldom exceeding 25 and deliver a water of color of 17 or less.

Hartford has raw water of excellent sanitary quality to start with, long storage and sparsely inhabited watersheds, making the question of a safe water for delivery of less importance in filtration than might otherwise be the case, and so making filtration rates of 5 and 6 mil. gal. per day per acre permissible.

The hardness of the Hartford water is very much less than that of the Cambridge water, making the slow sand filter perhaps a simpler process here than the other. With these things in mind it is not possible to say that Hartford has a better filter than Cambridge, or that Cambridge has a better filter than Hartford. There are certain conditions, of course, we all know, where there is nothing but a rapid sand filter that will work; it is impracticable to work anything else. There are other conditions where either slow or rapid sand filters can be used. It is a question of judgment. In still other places some of us think that the slow sand filter has advantages that the other does not.

The question perhaps comes down to, "what is a satisfactory color to deliver to consumers?" If we must have zero, or very close to zero — 5 or 8, perhaps all of the time — that is one thing, and only rapid sand filters can be used. If our people are satisfied with colors that will range not over 18, and for most of the time will go about 12 or 14, that is another matter. So taking it all together, I think it is really a question of the engineer's judgment, tempered with what the community desires, and after all public opinion is a good thing to heed, provided no irreparable harm is done or violation of principle is occasioned.

Mr. Frank A. Marston.* I have been much interested in listening to Colonel Johnson's paper and those that followed it, particularly as I have had the pleasure of examining the plant.

There are a number of features about the plant which interested me. One in particular was the use of a Venturi meter on the main wash-water line to control the flow of wash water. Plants have been built in which the reserve pressure of wash water has been such that a careless operator could open the wash-water valve too quickly or too far and seriously disturb the filter under-drainage system thereby. This has been the case not only with the Wheeler type of filter bottom but also with the more common form of pipe strainer and gravel bottom as well as others. The use of a Venturi meter for this purpose is more novel than the common method of putting a stop on the hydraulic piston rod of the wash-water valve so that it cannot be opened too far. The Venturi meter is easily adjustable and should be reliable.

Aside from the description of the filter plant, there is a point mentioned by Mr. Smulski in his discussion upon which there are grounds for a difference of opinion. This is in regard to the relative merits of the use of reinforced-concrete reservoir coverings as against the groined-arch

* Of Metcalf & Eddy, Boston, Mass.

covering. It makes some difference which part of the country the work is in as to the economy of one type of construction as against the other. For instance, a few years ago bids were received by the city of Dayton, Ohio, on a 10 mil. gal. distributing reservoir in which two types of construction were provided, — one, a flat-slab type, of which the Smulski system is an example, and the second a groined arch, which is more common to us here in New England than it is to those in the Middle West. In that case the only bidders were building contractors who were very familiar with flat-slab construction but had had little if any experience with groined-arch construction, and who had in their store yards large numbers of forms suitable for flat-slab construction. They may, also, have been prejudiced by the experience in Cleveland with groined-arch construction, which experience I believe was no discredit to the groined arch but was due to particular conditions encountered. The bids received showed a substantial advantage in the use of the flat slab over the groined arch. The reservoir was built with a roof of flat-slab construction and a floor of the inverted groined-arch type.

Another case: For the filtration plant of the East Chicago and Indiana Harbor Water Co., bids were received for the clear-water and sedimentation basins in the two types of construction, — flat slab and groined arch. The bid for the groined-arch construction was so little in advance of the flat-slab construction that it was accepted, and the groined-arch construction was used for both the roof and the floor.

The groined-arch construction has some advantages if the difference in cost is not too great. In some plants the cost of the groined arch has been low enough so that it probably was comparable with that of the flat-slab construction. The groined arch does not depend upon steel for its strength, and in building a long-lived structure I believe there is something to be said in favor of a structure which does not depend upon the life of steel but which depends upon arch action for its stability and the permanence of concrete for its life.

We have ample precedent to show that the groined arch is a stable, long-lived structure. This does not discredit reinforced concrete. Metcalf & Eddy in the design of the East Chicago plant, used flat-slab construction for the chemical house floors and, incidentally, used the Smulski system of reinforcement.

Another interesting feature of the Smulski system, perhaps of less interest to water-works men, is the method of computing the reinforcing. Mr. Smulski, if I remember correctly, in his discussion said there was no rational method of figuring a groined arch. I think it may be questioned whether there is any more rational method of figuring the Smulski system of reinforcing. Both can be designed satisfactorily to meet the requirements of a reservoir roof. There are engineers who will not give credit to the radial bars in the Smulski system, but this is a debatable question. In the design of the Smulski system which we used on the East Chicago plant, we did use the radial bars.

Mr. Smulski. As evident from Mr. Marston's discussion, we agree fairly well that flat-slab construction is generally cheaper than groined-arch construction. He cites two cases in which competitive figures were taken for both types and in both cases the flat-slab construction proved to be cheaper. This comparison was based on ordinary flat-slab design; the difference would have been still larger if the Smulski system had been used in the comparison.

Mr. Marston and I differ as to whether the groined arch or the flat slab should receive preference in case of close figures. Mr. Marston is in favor of groined arches because in his opinion it is a long-lived construction. I contend that reinforced concrete should receive preference. The question of longer life for groined arches is fairly doubtful. From the experience thus far it would seem that reinforced-concrete structures are equally permanent, at least for all practical purposes. Against the doubtful advantage of longer life there are the actual disadvantages enumerated in my discussion.

I agree with Mr. Marston that a number of successful groined arches have been built. But it cannot be contradicted that the groined arch is not stable by itself and that it depends upon the outside walls and the stability of the earth support for its strength. The designer does not always know what conditions will be found in the field. He figures on unyielding supports. If his guess is right and no accident happens to any intermediate arches during construction his structure is safe and will last indefinitely. Otherwise his structure tumbles like the Cleveland basin and the Madrid reservoir. These two are cited because they are most widely known. Nobody can deny that if reinforced concrete had been used in these cases failure would either have been averted or localized.

Mr. Marston states that there is no more rational method of figuring the Smulski system than that of figuring groined arches. I am sure that Mr. Marston would have difficulty in upholding this contention. The Smulski system is designed according to the regular flat-slab formulas. By means of these it is possible to provide slabs of a known factor of safety for any length of the span and any desired loading. Numerous tests prove that the formulas give the required factor of safety. If there is any such formula for groined arches, based on equally sound theory to that applied in the case of flat slabs and as thoroughly proved by tests and experiments, I do not know about it.

Mr. Marston also calls attention to the fact that "there are engineers who will not give credit to the radial bars in the Smulski system." Very likely this is true. I will even go farther and admit that there are engineers who for reasons best known to themselves do not give credit to the whole arrangement of the Smulski reinforcement. Since, however, the profession as a whole accepts the obvious fact that the system performs the work for which it is designed, and since in all our tests the radial bars are treated by the loads with proper respect and extensometer readings show

that they resist their share of the stresses, the utility of the radial bars is clearly indicated.

Colonel Johnson. The more pertinent points indicated by those who were good enough to discuss the author's paper are those raised by Messrs. Saville and Marston. The author desires not to overlook any of the discussions that were presented because he appreciates in the fullest degree the courtesies advanced by those who took exception to or commended the work under discussion.

Mr. Marston's commentary on the control of the flow of wash water seems to imply, unintentionally no doubt, that the Wheeler filter bottom is more subject than other types to derangement resulting from an excessively high rate of washing. This is not the fact. The distribution of the entering wash water is more uniform with the Wheeler bottom than with any other type, and this fact alone minimizes the possibility of disturbing the relative arrangement of the various sizes of gravel. No rate of washing which permits the sand to remain in the filter at all will cause derangement with the Wheeler bottom.

Mr. Saville intimates that he and the author may in all possibility part company on questions of methods of water filtration and cost. The author was a member of the Board of Experts employed by the city of Hartford, in whose name Mr. Saville now operates, in connection with their water-supply problem. The author gave them advice relative to the most efficient and economical procedure to follow in Hartford's problem; but Mr. Saville and his supporters were stronger than those of us who make a specialty of this business, and their judgment prevailed.

The question of cost relative to the construction cost of the Cambridge Rapid Sand Filter Plant and the Hartford Slow Sand Filter Plant are exceedingly pertinent at this moment. Mr. Saville had made, prior to the Burlington meeting, a distinct point that the cost of the Hartford works was lower per unit of filtering capacity than those at Cambridge.

Mr. Saville in his discussion has courteously referred to this intimate controversy in ways characteristic and kind of him. Nevertheless, the speaker must, in support of his own position, state that he believes Mr. Saville is thoroughly wrong in the attitude that he has taken. He desires to say that while holding the highest admiration for Mr. Saville as a man, he still has grave doubts about his judgment on slow and rapid sand filtration problems in the New England States.

The author has read very carefully Mr. Saville's detailed remarks explanatory of the reasons why Hartford installed a slow sand filter plant; and even though he thinks so much personally of Mr. Saville, he cannot subscribe to the salient arguments presented him.

HYDRANT CONNECTIONS FOR FIRE ENGINES.

BY FRANK A. MARSTON.*

[*Read September 20, 1923.*]

Fire hydrants should be designed and installed to give the greatest possible service in fighting fires, consistent with reasonable costs of installation and maintenance, and with due regard for the integrity of the water-works system.

The waterways in hydrants should be of sufficient size to prevent material losses in water pressure due to friction, velocity head, and other causes.

For the purpose of connecting hose lines direct to the hydrants, two $2\frac{1}{2}$-in. nozzles, or outlets, are commonly provided.

In municipalities where the fire department is equipped with steam fire engines or motor-driven pumping engines, the usual practice is to install hydrants having in addition to the $2\frac{1}{2}$-in. hose outlets, a $4\frac{1}{2}$-in. outlet to which the suction hose of the pump can be attached.

Desirable practice in this regard is indicated by the requirements of the National Board of Fire Underwriters. In the "Standard Schedule for Grading Cities and Towns of the United States with Reference to their Fire Defences and Physical Conditions," published by the National Board of Fire Underwriters, is found the following:

"Hydrants shall not have less than two $2\frac{1}{2}$-in. outlets and also a large suction connection where engine service is necessary."

Where the pressures in the distribution system are sufficient to permit satisfactory streams direct from hydrants, pumping engines may not be required by the Underwriters' schedule, but the proportion of municipalities where pumping engines are not used is decreasing. The modern motor-driven pumping engine with its greater speed of travel is being more generally adopted by fire departments than was the case with the steam fire engine. Furthermore, there appears to be a tendency to decrease pressures in distribution systems to the point of furnishing satisfactory service for domestic needs, and to throw the burden of developing fire stream pressures on the fire department apparatus.

Therefore, it may be expected in the future that there will be a more general use of pumping engines by fire departments, and, accordingly, hydrants, connections, and distribution systems should be designed with this fact in mind.

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Service Required of Hydrants and Effect of Pumping Engines.

An example of the severe tests to which hydrants in the larger cities may be put, is illustrated by incidents at a four-alarm fire on Congress Street, Boston, July 18, 1923. The writer is indebted to George H. Finneran, Superintendent Water Service, Boston, and E. M. Byington, Superintendent of Construction, Boston Fire Department, for the following details:

One hydrant of the Boston post type, having one $2\frac{1}{2}$-in. hose outlet and two $4\frac{1}{2}$-in. steamer outlets, during the early stages of the fire, had a connection by means of a large suction hose from one $4\frac{1}{2}$-in. outlet to a steam-driven reciprocating engine of about 750 gal. per min. capacity. The $2\frac{1}{2}$-in. outlet was connected by means of a large suction hose and reducer to a motor-driven rotary pump of about 1 000 gal. per min. capacity. With these two engines in operation, there was a noticeable vibration in the hydrant barrel. This hydrant is set in a chamber, and the hydrant barrel is not supported at the street level, the only rigid support being at the base and at the connection with the main. Additional streams were required and the so-called "Horseless Engine" was connected to the other $4\frac{1}{2}$-in. outlet. This engine is steam propelled, and has a stream-driven reciprocating pump of about 1 100 gal. per min. capacity. There is no record of the actual rate of flow of water through the hydrant, but the rate of draft was probably at least 3 000 gal. per min. with the three engines as operated. Under these conditions, the hydrant barrel swayed violently, and although various means were tried to provide support, it finally became necessary to disconnect the "Horseless Engine" to prevent wrecking the hydrant. A large air chamber was then brought to the scene and inserted between the pump suction and the suction hose leading to the hydrant outlet. This chamber had a dome top, was 10 in. in inside diameter, about 28 in. high, and was restricted to $4\frac{1}{2}$ in. in inside diameter at the base, where the connections were made. The installation of this air chamber reduced the vibration in the hydrant considerably. It was found by trial that the chamber was most efficient when attached to the pump suction rather than to the hydrant outlet. The water mains supplying this hydrant were ample in capacity, as shown by the fact that the pressure did not drop appreciably during the fire (see Fig. 1), but the hydrant lateral was only 6 in. in diameter and the flow in the hydrant pot was restricted by the valve, which opened in the direction of the flow of water. This was the second instance of trouble with this hydrant under similar conditions. In fact, whenever the "Horseless Engine" has been used with other engines at a large fire severe vibration has been caused at the hydrant.

The Congress Street fire, which was located in a five-story warehouse in a high-value, wholesale district, outside the limits of the high-pressure water system, furnishes an interesting subject for study of the demands on the water-distribution system during a large fire. Chief John O. Taber

kindly furnished details of the fighting of the fire. A description of the fire will be found in "Fire and Water Engineering," August 1, 1923, p. 217.

There were 16 engines in use, connected to 9 post hydrants and 2 Lowry flush hydrants, and furnishing a maximum of over 12 000 gal. per min. of water to 18 900 linear feet of hose. The average pump pressure was 143 lb. per sq. in., and varied from 120 to 200 lb. per sq. in. The apparatus and equipment was handled by 240 firemen.

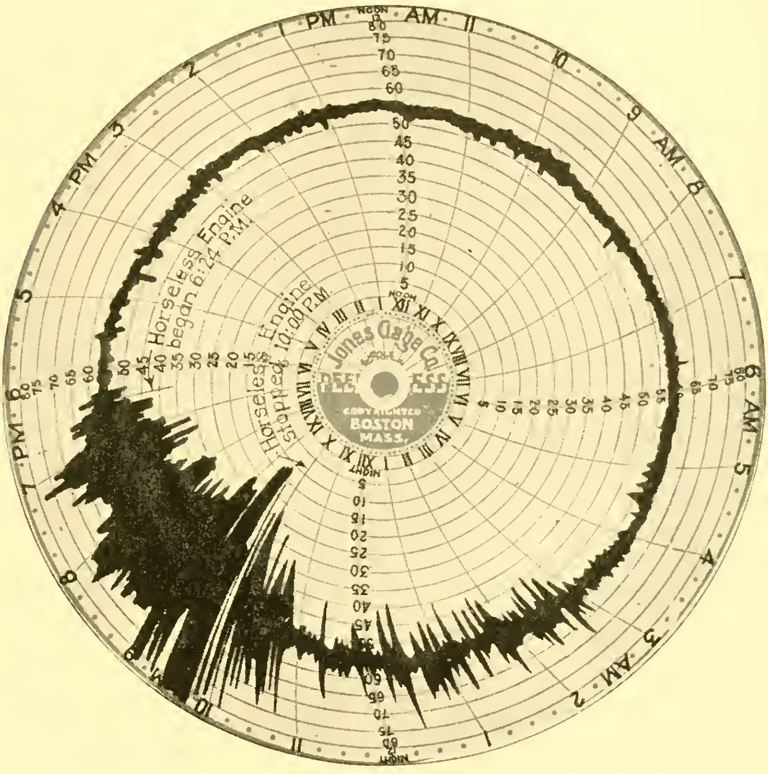

FIG. 1. — FLUCTUATIONS IN WATER PRESSURE IN DISTRIBUTION MAINS CAUSED BY WATER HAMMER FROM PUMPING ENGINES CONGRESS ST., BOSTON, MASS., FIRE, JULY 18, 1923.

A short distance from the scene of the fire in one of the fire department engine houses was a recording pressure gage, which made an interesting record of the water hammer in the distribution mains referred to above. This is shown in Fig. 1. The first alarm was sounded at 6.07½ P.M. The first engine began to pump at 6.10 P.M., and the "Horseless Engine" began to pump about 6.24 P.M., and was shut down about 10.00 P.M. Its effect was very marked. After the air chamber was installed it was again used on watch lines for about 39 hr.

At a fire in Charlestown where the "Horseless Engine" was used

the vibration was sufficient to loosen the four bolts which hold the base of the hydrant, and the hydrant barrel came off while the engine was working.

At a fire in Brighton two steamers of the reciprocating-pump type were attached to the two $4\frac{1}{2}$-in. outlets of a Boston post hydrant. One of the steamers was supplying one line of hose. The other steamer for some reason was not working. A motor-driven pumping engine was then attached to the $2\frac{1}{2}$-in. outlet, and four lines of hose were attached to the pump, each line supplying $1\frac{1}{4}$-in. nozzles. The pump was operated showing 12 in. of vacuum on the suction, but it was impossible to get satisfactory service, and it was found necessary to remove one of the hose lines to one of the steam-driven engines, leaving three lines on the motor-driven pump attached to the $2\frac{1}{2}$-in. outlet. From this observation and others, Mr. Byington is of the opinion that three streams of perhaps 250 gal. per min. each, or a total of 750 gal. per min., is about the maximum rate at which water can be satisfactorily drawn by a pumping engine through a $2\frac{1}{2}$-in. hydrant outlet.

It is the general practice of the Boston Fire Department, when an engine responds to a first alarm, to use a 3-in. soft-suction hose which has $4\frac{1}{2}$-in. couplings, and although the intention is to attach the engine to a $4\frac{1}{2}$-in. outlet it sometimes happens that a $2\frac{1}{2}$-in. outlet is used, if conditions seem to make it the most convenient outlet to use. Engines responding to second alarms use the 4-in. hard-suction hose, which has $4\frac{1}{2}$-in. couplings and attach the hose to a $4\frac{1}{2}$-in. outlet, if there is one available.

Serious trouble from vibration in hydrants in Boston has been almost entirely limited to the use of the "Horseless Engine," but at times when three of the smaller engines have been attached to one hydrant, considerable vibration has been noticed in the hydrant. If these hydrants had been buried in earth rather than installed in a pit, there would not have been as much trouble.

Instances have come to the writer's attention where hydrant barrels have been split or the hydrant blown off at the base due to the rapidly recurring water hammer or vibration resulting from the operation of pumping apparatus at high rates when connected to hydrants inadequately served by the distribution system. With reciprocating or rotary pumps which are of the positive displacement type of apparatus, and under such conditions it is possible to create a suction greater than can be satisfied by the flow of water. This apparently causes the water to come intermittently accompanied by violent water hammer, and stresses are set up, which the cheaper types of hydrants or poorly constructed connections and pipe lines cannot withstand.

Obviously, the operator of the pumping engine should neither be required nor allowed to speed up the pump beyond the capacity of the pipes and hydrant to deliver the water.

Difficulties of this kind are not likely to occur with centrifugal pumps. The smaller sizes of motor-driven pumping engines are not equipped

with vacuum chambers, but the larger sizes such as 1 000 gal. per min. capacity and over, have small vacuum chambers. Where vacuum chambers are provided, but little vibration is caused by the operation of the rotary pumps and even where no vacuum chambers are provided the vibration from the rotary pumps, which operate at relatively high speed, is much less than that obtained from the operation of the old type of reciprocating steam-driven pumps. It has been found that after from one to two hours' continuous operation vacuum chambers lose their air content and it becomes necessary to stop the engine and drain out the water. Therefore, some vibration may be transmitted to the hydrant even with motor-driven rotary pumps equipped with vacuum chambers.

While it is true that when running at equal rates of discharge, the steam-driven reciprocating pump will cause a greater vibration than the motor-driven rotary pump, there seems to be some ground for thinking that the danger of getting vibration is a little greater with motor-driven pumps due to the greater ease with which they can be driven at full capacity or even under an overload.

Fortunately, experiences like the foregoing are not of frequent occurrence. Normally, a hydrant is called upon to supply water for two or three lines of hose at a maximum rate of perhaps 600 to 750 gal. per min. or less.

At these rates of discharge and where ample pressure is availabel, the size of outlet used and method of connection are not matters of great importance.

In districts where the ordinary pressure maintained in the distribution system is 75 lb. per sq. in. or over (omitting special high-pressure systems), it has frequently been the practice to install hydrants with hose outlets only, and to omit the steamer outlet. This seems to the writer ill-advised for two reasons:

First, in case of a serious conflagration a larger number of fire streams than usual will be used, and the pressure in the entire district will be materially reduced — probably to the point of requiring engine service to maintain satisfactory fire streams. For the ordinary fire of course, this is not so.

Second, it occasionally becomes necessary, due to unusual conditions, to connect hose lines to a hydrant located some distance from a fire, with the result of lines 1 500 to 2 000 ft. or more in length. Under such conditions even 90 lb. per sq. in. pressure will not give satisfactory service, and the services of a pumping engine will be desirable to raise the pressure, perhaps, up to 250 lb. per sq. in. Communities that at present have no engines of their own occasionally require help from outside, and furthermore, it will not be many years before pumping engines will be used by practically all fire departments.

Therefore it would appear that the slight additional cost necessary to provide at least one steamer outlet, is justified.

Loss of Head in Hydrant Outlets.

The National Board of Fire Underwriters in the "Standard Schedule," page 32, specify.

"Hydrants shall be able to deliver 600 gal. per min., with a loss of not more than $2\frac{1}{2}$ lb. in the hydrant and a total loss of not more than 5 lb. between the street main and outlet . . . ."

Newcomb's Holyoke hydrant tests reported in the Journal of the New England Water Works Association, December, 1907, page 421, show for the hydrants without independent gate valves on the outlets and with barrels 5 in. in inside diameter and greater, losses due to friction varying from 1.21 to 3.21 lb. per sq. in. at a rate of flow of 500 gal. per min. with one fire stream. For the hydrants having independent gate valves on the outlets, the losses due to friction varied from 2.92 to 8.28 lb. per sq. in.

The loss of head due to friction of flow of 600 gal. per min. through a $2\frac{1}{2}$-in. outlet averages about 2 or $2\frac{1}{2}$ lb. per sq. in., if there is no independent gate valve on the outlet, and for a $4\frac{1}{2}$-in. outlet only about one-tenth as much, according to George W. Booth, Chief Engineer, The National Board of Fire Underwriters.

600 gal. per min. flowing.
$2\frac{1}{2}$-in. diameter outlet, velocity 39.4 ft. per second, velocity head 24.14 ft.
6-in. diameter barrel, velocity 6.8 ft. per second, velocity head 0.72 ft.
Difference in velocity head $= 24.14 - 0.72 = 23.42$ ft.
$2\frac{1}{2}$ lb. per sq. in. is equivalent to 5.8 ft. head of water.
5.8 ft. due to friction $+$ 23.4 ft. due to velocity $=$ 29.2 ft.

To the friction loss of $2\frac{1}{2}$ lb. per sq. in. must be added the head necessary to develop the required additional velocity of the water in the outlet over that in a 6-in. hydrant barrel amounting to 23.4 ft., thus making a total head of 29.2 ft. necessary in the main at the elevation of the center of the hydrant outlet. While some of this head may be recovered after passing the outlet, particularly if an increaser is used between the outlet and the suction hose, the most of it is probably lost. For higher rates of flow, the loss of head will be greater. These losses appear sufficient to justify wherever practicable the use of the steamer outlet for engine suction rather than to make the connection by a Siamese coupling to two $2\frac{1}{2}$-in. outlets. It may be that where ample pressure is available, the loss of head suffered by using a larger suction hose with a reducer connected to one $2\frac{1}{2}$-in. outlet is not sufficient to offset the advantage of handling the smaller coupling. If, however, there is an independent gate valve on the outlet, the loss of head is likely to be objectionably large.

General Practice in Regard to Hydrant Outlets.

The following comments by George W. Booth are the results of the observations of the engineers of the National Board of Fire Underwriters:

"Our engineers are in frequent touch with fire chiefs and water-works superintendents and have an excellent opportunity to find out their opinions and to learn of local conditions.

"We have never heard of a case where damage to the hydrant or to the main resulted from the use of the large outlet. There is a possibility of the hydrant nipple being jarred loose as a result of vibration transmitted from the steamer or the motor pumper especially if a stiff suction is used; however, this possibility is just as likely to occur with the $2\frac{1}{2}$-in. outlet as with the larger one.

"Our engineers report that practically all fire chiefs in the East use the large outlets when provided and would very much object to the installation of hydrants not having large outlets. In the Middle West the testimony is that large outlets are generally used when available. There are, however, many municipalities which have water works designed to carry a high enough pressure during fires to supply streams direct from hydrants, which have therefore only the $2\frac{1}{2}$-in. outlets. Now that the use of pumpers is becoming more common, there is a tendency to reduce pressures and this in our opinion has some advantages.

"In many of the larger cities, Detroit and St. Louis, all or nearly all hydrants have *none* but large outlets.

"While it is true that the function of the fire engine is to furnish water at the necessary pressure, it is also true that the capacity of the pumper is primarily determined by the horse power of the engine and every pound of pressure that can be applied to the suction side of the pumps increases the capacity of the pump, and friction losses which can be readily eliminated should be avoided. Even though the pressure at the hydrant may be normally sufficient to furnish adequate supply through a $2\frac{1}{2}$-in. outlet, the local friction losses in the mains which result from the use during a large fire of excessive quantities of water within a small area, will so reduce the pressure that a larger outlet is required for adequate supply.

"To sum up, I believe there is no valid argument against the use of the $4\frac{1}{2}$-in. outlet and a number of good arguments in its favor."

In response to the writer's request, E. V. French, President of the Arkwright Mutual Fire Insurance Company, ascertained the views of their engineers and wrote the following comments:

"We have been unable to find any experience which would indicate that a $4\frac{1}{2}$-in. hydrant outlet constitutes a hazard to either hydrants or distribution systems. A $4\frac{1}{2}$-in. hard-suction pipe would probably transmit somewhat more vibration from an engine than a $3\frac{1}{2}$-in. or $2\frac{1}{2}$-in. hard pipe, but we should not expect the difference to be serious or of any real importance with a properly designed hydrant.

"In cities with good water pressures, such as Woonsocket, R. I., engines take water sometimes through ordinary $2\frac{1}{2}$-in. hose using two hydrant outlets. In New Bedford experience has shown that sufficient water could not be obtained with two $2\frac{1}{2}$-in. connections if the water pressure in the mains fell much below 50 lb., so that in all cases in New Bedford the $4\frac{1}{2}$-in. suction connection is used. There have been cases where a single $2\frac{1}{2}$-in. soft-hose connection has collapsed under the suction produced by the engine.

"In some cities $4\frac{1}{2}$-in. hard hose is used with a reducing coupling which can be attached to the $2\frac{1}{2}$-in. hydrant outlets, thus restricting the inlet for only this single point and consequently obtaining a good deal more water than if the suction pipe was $2\frac{1}{2}$-in. all the way. However, in the majority of cases in this vicinity (Boston), at least, $4\frac{1}{2}$-in. hard-suction pipes are used."

John S. Caldwell, Engineer, New England Insurance Exchange, expressed his views on this subject as follows:

"We have never found in our work here in New England any sentiment among either water-works or fire department officials which would tend to discourage the installation of the large connection.

"Relative to the vibration which may be experienced in the hydrant due to the connecting to a modern motor pumping engine through the $4\frac{1}{2}$-in. connection, would state that I do not believe this is so, as we would expect more vibration from the old reciprocal type of pump when in use with a steamer than what we would get with the more modern machine. Of course, it is common practice for fire departments to use a $4\frac{1}{2}$-in. by $2\frac{1}{2}$-in. reducer for connection to engines where only a small quantity of water, like a single stream, is desired, but when the engine is required to work up to capacity, unless they happen to be on a hydrant with exceptionally good pressure, they very frequently are unable to get ample capacity through a $2\frac{1}{2}$-in. connection.

"I think I am perfectly safe in assuring you that there is no sentiment here in New England, as we have observed the conditions that would tend to discourage the installation of the larger engine connection and, as stated above, I believe the opposite is true, namely, that there is a movement on foot in the replacement of existing hydrants with ones having the larger connection, and in our grading of the fire protection throughout the different cities and towns we make a deficiency charge for the lack of engine connections on hydrants."

Chief Ross B. Davis, Bureau of Fire, Philadelphia, by courtesy of S. M. Van Loan, Deputy Chief, Bureau of Water, contributed the following:

"Our hydrants which have a 4-in. outlet and $4\frac{1}{2}$-in. suction hose permit us to take three and four lines from the one steamer, and we would never allow over two lines to be taken from a pumper or steamer with a $2\frac{1}{2}$-in. suction, unless reducing the tips of the nozzles, and that reduces the volume."

C. M. Saville, Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn., stated that all of the hydrants being installed in Hartford, Conn., have two $2\frac{1}{2}$-in. hose outlets and one $4\frac{1}{2}$-in. steamer outlet.

William W. Brush, Deputy Chief Engineer, Department of Water Supply, Gas and Electricity, New York, wrote:

"Our standard hydrant has one $2\frac{1}{2}$-in. and one $4\frac{1}{2}$-in. outlet. We have never had any complaint that has come to my knowledge of difficulty through the use of the $4\frac{1}{2}$-in. steamer outlet. I personally believe that it is a mistake to use small outlets, that there is no danger to the hydrant with the $4\frac{1}{2}$-in. outlet, and that with the increase in the size of the pumping engines the standard hydrant should carry a $2\frac{1}{2}$-in. and a $4\frac{1}{2}$-in. outlet."

George A. Carpenter, City Engineer, Pawtucket, R. I., reports that there are *no* hydrants in the city with $4\frac{1}{2}$-in. steamer outlets. This appears to be contrary to the practice of most New England cities. Inquiries by the writer in Indianapolis, St. Louis, and Dayton, where large steamer outlets are generally provided, failed to disclose any instances of trouble which could be attributed to the use of such outlets.

Support for Hydrants.

The hydrant outlets must be securely fastened to the hydrant barrel, which fact is recognized by the manufacturers of high-grade hydrants. Not all water-works builders, however, recognize the necessity of securely fastening the hydrant barrel to the lateral and main to prevent its being blown off. Where the main pipe is but a short distance from the hydrant, chains or bolts may be used to secure the hydrant. Concrete blocks cast behind the hydrant have also been used. Where dependence is placed on earth back fill or loose rock fill, the hazard to the hydrant is much greater. It is true that many hydrants have been set without special precautions being taken to properly support them, but it cannot be considered good practice. Earth back fill, well rammed, will provide sufficient lateral support except at the back. Where the hydrant is set in a heavy pavement, or concrete sidewalk, ample lateral support is ensured, but such support should not be relied upon to secure the base of the hydrant. If the hydrant is adequately supported and of first-class design and manufacture, it may safely be depended upon in time of emergency.

Conclusions.

1. The use of $4\frac{1}{2}$-in. steamer outlets on hydrants, in addition to two $2\frac{1}{2}$-in. hose outlets, is desirable where pumping engines are likely to be used. In the larger cities it is probably better to provide two large steamer outlets and only one $2\frac{1}{2}$-in. outlet.

2. During the past ten years there has been a tendency to increase pressures in distribution systems, but now the trend of good practice appears to be toward a reduction to the former pressures to provide for domestic service, with dependence on fire department pumping apparatus for fire stream pressures.

3. Steamer outlets should be provided even where the ordinary pressure is ample for two-hose streams, to make possible the draft of water at higher rates with a pumping engine in case of a serious fire or other emergency.

4. The distribution system should be capable of delivering water to the hydrants at rates consistent with the demands of modern fire-fighting methods.

5. During a serious fire, hydrants may be subjected to considerable vibration due to heavy drafts of water. To prevent failure in such a critical time, the hydrants should be of heavy construction and firmly supported. Special precautions should be taken to prevent the hydrant blowing off from the lateral at the base.

6. According to the Underwriters' rating a municipality will be penalized if there is a deficiency in steamer outlets, where engine service is required.

7. It is desirable to install steamer outlets even where a pressure of 75 lb. per sq. in. is ordinarily maintained, to provide for engine service in emergency.

8. There appear to be several good reasons why at least one large steamer outlet should be provided on every hydrant in a standard pressure water distribution system, and no valid reason against providing such an outlet.

Discussion.

Mr. S. H. MacKenzie.* I would like to inquire what type of hydrants the speaker would recommend for the places which have long lines of 4-in. and 6-in. main pipe. Would the centrifugal pump for fire service be the most satisfactory to use, and would there be less danger with such a pump of drawing more than the safe capacity of the main?

Mr. Marston. In regard to the centrifugal pump for fire department use, I am not an authority, but I understand that fire department officials do not generally favor centrifugal pumps because they do not get the same amount of suction with them that they can with the rotary pumps.

On the type of hydrant, that is pretty hard to say, not knowing the conditions, but my impression is that with 4-in. and 6-in. mains feeding the hydrants and with the motor-driven pumping apparatus, there would be times when the demand would be greater than the mains could supply. Even then you would be better off with a $4\frac{1}{2}$-in. outlet than with a $2\frac{1}{2}$-in. outlet, which would further throttle the pump suction.

Mr. MacKenzie. I was not thinking so much of the size of the outlet of the hydrant as of the type of pump. Would the danger from water hammer and overdraft be less with a centrifugal pump than with the other types used?

Mr. Marston. You mean, the centrifugal pump by the fire department?

Mr. MacKenzie. Yes. For instance, a short time ago, when flushing, we opened a hydrant at a low point and drew the water from the high points on the line. The question arises in my mind what will happen when a fire pump is attached under such conditions and what style of pump is most suitable for use?

Mr. Marston. I doubt if you would get any damage with a centrifugal pump, but you might with a rotary pump. The damage might occur in the hydrant, or near-by mains, or in the services, wherever there was a spot too weak to resist water hammer. If the water distribution system is well built and the pumping engine reasonably well operated there would be but little danger of such damage.

* Superintendent, Water Department, Southington, Conn.

MR. HENRY T. GIDLEY.* I would like to ask what reason they give in New York City for having only one $2\frac{1}{2}$-in. outlet with the $4\frac{1}{2}$-in.?

MR. MARSTON. I do not know the reason.

MR. J. M. DIVEN.† The high pressure have two $2\frac{1}{2}$-in. and one $4\frac{1}{2}$-in. outlet.

MR. W. C. HAWLEY.‡ I have been particularly interested in this paper because I have had this problem put up to me, although in a different way. I agree with Mr. Marston that for ordinary pressures the $4\frac{1}{2}$-in. nozzle is desirable.

The problem which I have had was a demand for $4\frac{1}{2}$-in. nozzles with pressures from 140 to 175 lb. I made inquiries of a number of men who had had experience, and almost without exception they said that under those circumstances they would not set a hydrant with the large connection, it is not necessary. I only found one place where they were doing it, but in that case when the firemen connect with those hydrants, carrying, I believe, something like 200 lb. pressure, they put on a reducer to $2\frac{1}{2}$ in. and use no steamer or pump.

We had an experience with a test, so-called, which was made during January of this year. The test was made by the municipal authorities without any notice to the water company. Seven fire streams were thrown through various lengths of hose ranging in length from 350 to 500 ft. and through $1\frac{1}{8}$ to $1\frac{1}{4}$-in. nozzles. Then they attached a pump to a hydrant diagonally across from one of the hydrants already in service, to which hydrant there were 500 ft. of hose with a $1\frac{1}{8}$-in. nozzle. No pressures were taken at the hydrants either before, during, or after the test. The only pressures that were taken were at the nozzles while the seven fire streams were being thrown, and after the pump was started they again took the pressures at the nozzles. The gentleman who was supposed to be running the test broke into print the next day with the statement that "millions of dollars' worth of property and hundreds of lives were jeopardized" because they only had from 40 to 75 lb. of pressure at the nozzles. Reference to the tables will show these to be "good" to "unusually strong" fire streams.

There was one interesting thing about that test. It happened that one of our men had been in the office late that evening and on his way home saw what was going on. When the pump was in service it was throwing a little less than 800 gal. per minute, and the other streams in the neighborhood 2 100 or 2 200 gal. per minute more, as I remember it. Under those conditions there was 40 lb. pressure on the suction side of the pump. The order was given to shut down the pump, and later it was started up again. When they shut it down they closed the hydrant. When the pump was started the second time they "opened" the hydrant, but there

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* Superintendent, Fairhaven Water Company, Fairhaven, Mass.

† Secretary, American Water Works Associaton.

‡ Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

was no pressure on the suction side until our man found that the hydrant was only partly open. He opened the hydrant and then there was 100 lb. pressure on the suction side. This hydrant did not have a steamer nozzle. The water was taken from a $2\frac{1}{2}$-in. hose connection.

The failure to open a hydrant is one of the things that has given me more trouble, so far as my relations with the fire department are concerned, than any other one thing. I remember a very serious fire where we were blackguarded by the firemen for lack of pressure. It happened that one of the commissioners came along and opened the hydrant, and then they had an abundance of water. The firemen had opened it only three or four turns. We have been up against that a number of times, and I think that is one of the things which we should watch, especially in the case of volunteer fire departments, although I have known such things to happen in paid departments.

Referring again to the test which I have mentioned: about four months later we had a real test at a fire in the same block. The fire got a bad start in the basement of a large building in a thickly built-up district. Seven fire streams were in service, most of them from the same hydrants which had been used in the test. There was an ample pressure and an abundance of water and the fire was soon extinguished.

We have decided not to set hydrants with large connections. We have an abundant pressure, and, frankly, I am afraid of the jar of the pump shaking the hydrant from the lateral. We have had trouble with steam fire engines, although no hydrants have blown off, but I know of cases where that has happened, and I am afraid with our pressures, of what may happen.

The municipality which wanted us to set hydrants with $4\frac{1}{2}$-in. nozzles was very insistent, and we finally replied that we would set the hydrants if the municipality would assume the responsibility for any accident which might happen. They would not assume that responsibility, and we set the hydrants with the small nozzle.

Mr. Caleb M. Saville.* I was interested in what Mr. Marston has said about losses of pressure in the hydrants. We have made quite a number of tests of hydrants at Hartford, to ascertain the loss of pressure in various parts of them, and the information thus far indicates that the principal losses are in the outlets. Most of the hydrants that are made, even with 4-in. barrels, seem to have plenty of waterway, and if the hydrant manufacturer could be induced to make some improvement in the $2\frac{1}{2}$-in. outlets it would be of a considerable benefit.

Mr. Marston spoke of a tendency to reduce pressures. I am not sure that that is a general condition, although it may be so in towns or cities where a pumping plant is used; that is, where it is not necessary, perhaps, to have the higher pressures all of the time. In those cities that are fortunate enough to be supplied by gravity it seems to me that there is a tendency

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

the other way; that is, to get higher pressures and put on reducing valves in the lower parts of the district if the pressure is too high. In Hartford we recently have had several very high buildings erected and the pressure is none too high. In the lower part of the city, the pressure is high — 100 to 125 lb. — and reducing valves are being put on to some extent. In the higher buildings and in the higher parts of the district the pressure now used has eliminated the use of independent pumping engines, greatly to the pleasure of the people there supplied.

Mr. David A. Heffernan.* We have a Mutual Aid agreement with a contiguous municipality. At a two-alarm fire one cold day last winter we experienced a rather unusual occurrence.

Our hydrant nozzles are equipped with standard thread. The municipality mentioned has a mongrel thread on its 4-in. suction. Therefore, both fire departments carry adapters. When more apparatus responded which did not carry the adapter the 4-in. suction could not be used and much valuable time was lost before these outside firemen discovered that the thread was different from the one they were used to.

The same fire department experienced trouble with every Milton hydrant they tried to operate. Their hydrants are of the compression type, while ours are of the sliding-gate type. The latter open harder. In two cases these outside firemen were unable to open the hydrants with their short wrenches and thought they were frozen. In each instance the hydrant was opened by water-department employees.

I have always considered it essential for a water-department man to attend fire alarms. In the case of our department this is simplified as two of our men are members of the call force.

Mr. MacKenzie. We had a little experience a few days ago which showed the great value of pumping apparatus, and also the value of uniform threads. We had a fire at a camp ground in our town, and the fire department from Plainville, three miles away, and New Britain, eight miles away, responded. Plainville furnished the hose and New Britain the pump. As the fire was 2 600 ft. from the hydrant the stream was almost useless until the pump was connected. Coöperation, uniform hose threads, and a pump saved all but two or three cottages at the camp grounds.

In many communities the mains are small and the hydrants are located far apart and many also have high sections with low pressures. Under such conditions a combination auto chemical and pump is a valuable asset, as shown in the case above.

Mr. Charles W. Sherman.† What I have to offer is not on the subject of Mr. Marston's paper, but it is suggested by one of the points raised by Mr. Heffernan and may not be out of place in this discussion; that is, the lack of knowledge on the part of some fire departments, par-

* Superintendent, Water Works, Milton, Mass.

† Of Metcalf & Eddy, Boston, Mass.

ticularly the smaller ones, of the proper operation of hydrants or any other water-works apparatus.

It came to my knowledge two or three years ago that in a small town the fire department complained to the water department that the hydrants were in bad condition. They said they had very nearly lost a valuable building because they could not operate one hydrant. This resulted in a joint inspection by the water and fire departments of all hydrants in the town, and in the course of that inspection it developed that the hydrants themselves were all in good mechanical condition, except the operating nuts of some, which had been badly chewed up. In a few cases it appeared that that had resulted from the more or less common use of a Stillson wrench when using hydrants for other than fire or water department purposes; but in a number of cases it developed that it had come from the use of the fire department wrenches, and further investigation proved that instead of using regular hydrant wrenches they had some wrenches made by a blacksmith which were not properly fitted to the hydrant nut.

Mr. R. W. Wigmore.* I am particularly interested in the paper because of the fact that practically all the suggestions given by the paper have been followed in the city in which I live.

Speaking particularly of the lack of coöperation between the water department and the fire department, I would say that we have a man who has absolute charge of the hydrants. He attends every fire; in fact, he is at the fire almost as quickly as the fire department, so that if anything is wrong with the hydrant he can have it attended to at once. He is a practical man. In the winter time, in very severe weather, we have a daily inspection of the hydrants, and in a winter that is not so cold, we have an inspection every other day. So that it is almost impossible for a hydrant to be wrong under these conditions.

I would like to ask Mr. Marston what size lateral he would suggest from the main to the hydrant. In our case we use nothing smaller than a 6-in., even with an 8-in. main. Of course where the main is smaller we use a 6-in. entirely.

Mr. Marston. Where the hydrant connection is of short length, 6-in. pipe is commonly used, and is satisfactory. Smaller pipe should not be used. For important hydrants of large size (with 8-in. barrels) connected to water mains of ample capacity, an 8-in. connection is justified.

Mr. Henry V. Macksey.† Referring to just one point outside of the paper, which was brought up by our President-elect, regarding the coöperation between the fire department and the water department. I believe in coöperation, but I do not believe that real coöperation consists of putting one man's duty and responsibility upon another man. Now, instead of being so insistent on having a competent hydrant man from the water department attend every fire and be able and willing to tell every

* Commissioner of Water and Sewage, St. John, N. B.

† Superintendent, Public Works, Framingham, Mass.

fireman how to operate a hydrant, I think, if there is to be coöperation it should be in the water department insisting that the firemen should be sent to them to be instructed how to operate hydrants properly, and that it is not so necessary that there should be a competent man from the water department to open the hydrants as it is that there shall be competent men from the fire department to open the hydrants. In other words, when the fire department asks you to coöperate you should do so, but do not assume the responsibility of operation. Where the authority is, there also should the responsibility be, and when the fire department takes charge of a hydrant at a fire, a water department man has no right to interfere, and has no authority there until he is called in by the fire department, and it should not call him until the hydrant fails to work properly.

Therefore, I believe that it is good practice to have a competent water department man at the fire in case an accident occurs, or the firemen, either due to excitement or ignorance, make a mistake in the operation of the hydrant. Then the water department man should be there, if possible, to help. But that is not the principal duty of the water department in connection with hydrant service. The principal duty of the water department is to make the coöperation mutual and to instruct the firemen as needed and to advise them to send their wrenches to the water department, to see that they are properly made. We all know in time of excitement a fireman will use a Stillson wrench, and if nothing else is handy you cannot blame him even though he injures the hydrant stem. The water department inspector after the fire should take care of that trouble even if it requires a new stem.

Your coöperation is needed to instruct firemen how to operate a hydrant in time of fire, but not during the fire.

Mr. Heffernan. I would like to state that the water department men are members of the fire department also. I am a member myself. So that is the reason why we do not like to have anything put over on us if we know it is not the fact. It is like the case of the frozen hydrant.

Mr. Diven. There is an adjustable fire hydrant which can be adjusted if the nut is partly worn, which fire departments might use. Mr. Saville spoke of the lessening resistance in the outlets of hydrants. I asked him how he proposed to do it. I would suggest to him that there is a committee on Standard Fire Hydrants still in existence in the Association, and he might take the matter up with them.

A Member. I just want to suggest that the presence of the Stillson wrench might be laid to the average water-works superintendent, for the reason that he does not have his hydrant connection, $4\frac{1}{2}$-in. in diameter, loosened sufficiently for the average fireman to open it, and the fireman always provides himself with a Stillson wrench so that he can open it in an emergency.

Mr. Heffernan. As a matter of coöperation I had three wrenches made, and I presented them to the department, so that they would not have any further trouble. Of course the cast-iron wrenches are 2 ft. in

length and no leverage on them. The hydrants are of the compression type and the gate hydrant works harder.

President Sanders. I would like to get a little information myself. Of course the President should not enter into the discussions; but we have a large number of individual valve hydrants, and at every fire we have to use one of the individual valve hydrants, and when they get through using it and we get back to the hydrant, we almost always find the valve in the bottom of the hydrant. It does not seem to make much difference what kind of hydrant it is. I would like to know if it is the general custom of the men present here to use individual valve hydrants, or if they put the valve on the nipple on the outside of the hydrant? Of course that is done in a factory yard, but whether that is a proper thing on a street is another matter.

Mr. Marston. I believe the best practice is to omit individual gate valves from hydrant outlets, particularly $2\frac{1}{2}$-in. outlets. The fire department can easily carry such valves. The valves will then be removed after the hydrant has been used, and the trouble referred to will be obviated.

Mr. Saville. I would say that in Hartford they have one or two of those individually gated hydrants, but in other cases the fire department carries independent valves with them which they put on themselves.

Mr. Sydney L. Ruggles.* It is the practice in our city to have one or two men in the water department as call men in the fire department, so that in the case of a general alarm they go out and act as members of the fire department. Also, of course, when the firemen have drills, the call men, the water department men, are expected to go, and they are assigned to handling the hydrants in the assignment of the call men.

Mr. Gidley. Some of the remarks of the former speakers make me think of some of my experiences. Just this summer they bought a new pump in the town. Before they bought the pump there was great discussion of whether we could furnish enough water for the pump. So when they got the pump they took it out, of course without notifying the water department, and put it on a dead end, and were very much astonished — we had 85 lb. pressure. They worked the engine full capacity and they still had all the water they wanted, and they were very much surprised at that. So they took it out again without telling us, and that time they put on all the streams they could in that vicinity, and they were satisfied we had enough water to run the pump. But a short time after that there was a still alarm and they attached the pump to the hydrant, and they said they did not get any water from it. They telephoned to the pumping station to know if we had any water in the mains. The trouble was that they had only opened the hydrant a few turns, and when they opened the hydrant in good shape they got plenty of water. That seems to be a great trouble with them. Of course in a general alarm a member of the water department would probably be there, but in that case of course he didn't know anything about it.

* Superintendent, Water Department, Barre, Vermont.

THE CARE OF LARGE WATERSHEDS.

BY FREDERIC I. WINSLOW.*

[*Read September 19, 1923.*]

After the various excellent papers which have preceded this one, and with those which are to follow in mind, I confess to some slight feeling of embarrassment in presenting a paper on a subject which can hardly claim the merit of possessing much that is new to those of our members having the care of watersheds. But as there are many persons occupied in work similar to what is described here, it is hoped that the paper may at least be of some value to water-works men.

In the annual report of the Metropolitan Water Board for the year 1917, a sentence occurs expressing the opinion of the Board as follows: "It may be claimed with entire justice that the ability adequately to maintain a complicated system of water supply requires qualifications not inferior to those of the men employed in the original construction of the works, however they may differ in character." While the writer cannot wholly agree with the above high estimate of the ability required to maintain existing works, realizing that designers, construction engineers and foremen usually receive a greater remuneration than those on permanent work, and usually that after the larger jobs are completed the better or higher grade of men go and the inferior ones remain to carry on the work; yet the fact remains that there is a considerable degree of responsibility in the successful operation of large water-works systems.

Perhaps the first care on a watershed to-day is to control a large area on the perimeter of the main supply reservoirs. Even the private companies feel impelled to do this as we have seen at Bridgeport and elsewhere. With a sufficiently wide right of way around the reservoirs, with adequate laws to prevent boating, bathing, and other forms of pollution, and a sufficiently large patrol force to keep the public in some awe of consequences, the water drinker may feel fairly safe, or as safe as one could feel with an unfiltered and untreated water.

The matter of planting all available areas has been so thoroughly discussed before you that I would not take the time to enter upon it further than to emphasize the importance of planting and to say that in general probably some variety of pine is the best adapted to New England. I quote on this point, E. H. Frothingham (Bulletin 13, Dept. of Argiculture, U. S.), who states; "Of all the trees of Eastern North America, white pine best combines the qualities of rapid growth, heavy yield and ease of management, but grows best in deep, fresh, loamy soils." He claims that

* Division Engineer, Metropolitan District Commission; Consulting Engineer, Framingham, Mass.

four to six per cent profit may be made on the investment, excluding taxation.

In a number of states wooded areas are exempted from taxation, either wholly or in part, when such areas are planted for the purpose of conserving a privately-owned water supply. The usual spacing recommended is six feet apart. Quoting again from E. H. Frothingham, "Balsam fir, which is planted to the extent of twenty per cent in New England, is inferior to white pine or spruce." As some question has arisen regarding the merits of white pine, I quote from a recent letter from C. R. Tillotson, Acting Chief, Branch of Forest Management, U. S. Dept. of Agriculture, who writes, "As a precautionary measure, some foresters are advocating the substitution of red or Norway pine for white pine, at least in part." This statement is made relative to the damage to white pine from "blister rust," and Mr. Tillotson further states, "If allowed to go on unchecked, this disease will, in the opinion of the Forest Pathologists who have given it the most study, do a great deal of damage to white pine. These same men, however, are of the opinion that the disease can be kept under control through rather inexpensive measures, and that it need not therefore interfere with the growing of white pine in regions where the white pine is particularly well adapted for growth." It is customary to eliminate all raspberry and gooseberry bushes from the proximity of these trees. What is called paper birch is sometimes recommended, as this has considerable commercial value, being used for spools, shoe pegs, toothpicks, dowels, shanks, etc. Red spruce may also in some cases be planted to advantage, the wood being used in topmasts, framing, and in vessels where oak is scarce.

It is certainly important to plant trees wherever possible, as according to the best authorities the supply of lumber in this country will be exhausted in fifty years. Massachusetts now imports about eighty per cent of her lumber supply, where within the memory of men still living she was a large lumber exporting state. It is refreshing to note that a few towns are even planting town forests, among these being three in Massachusetts, Fitchburg, said to be the first in the United States, Walpole and Brookline. The importance of spraying in the spring should not be forgotten. The customary strength of the arsenate of lead solution is 10 to 12 lb. to 100 gal., and 500 lb. of the solution will cover about one acre of grown trees.

This brings us to the matter of fire prevention, which is one reason for having a fairly large force of men, who spend a large portion of their time in trimming the trees, in cleaning up underbrush and in maintaining fire stops, which are ordinarily 40 to 50 ft. wide, and not over 600 ft. apart. All slash should be disposed of and material should not be piled in windrows as it is too easily spread, if a fire should start, as the use of water is rarely feasible.

The covering of large areas by watchmen is more of a coercive measure than anything else, as there is little doubt that where residents in camps

near a sheet of water can do so without the risk of being arrested they will use the water for almost any purpose. It is not always easy either to interest a judge in a violation of the law, especially where the water is taken from a small town for a larger one a long distance away, and local public sentiment has to be considered in the bringing of breakers of the law to justice. The inspection of watersheds for all sources of direct pollution, however, must be persistent and continuous, for here we have public sentiment on our side, as a rule.

On the Metropolitan system no cesspool or privy can be maintained within 50 ft. of high-water mark of any open waters pertaining to the system, nor can any noxious liquid be placed on the ground within 250 ft. of high water, and no stable nor henhouse can be maintained within 50 ft. of high water. Hospitals and slaughterhouses are compelled to conform to state laws in general relating to permission, etc. Cutting of ice is permitted under permit and inspection, and all droppings must be removed promptly. If all cutting could be made by the compact machines now on the market, it would be a step in advance. In the crossing of aqueducts, all pipes are or should be compelled to be laid with tight joints and no crossings should be made without previous notice, allowing opportunity for inspection and investigation.

Passing on to the subject of dams, the first and most important matter is that of observation of leakage. Usually, observation of the leakage through a dam is arranged for by providing a sump where a weir is sometimes built, permitting the observation of any change in the flow. Most dams leak to some extent, but those under the notice of the writer do not appear to show much change from year to year. If properly built, masonry dams do not require much attention except as to flow over or through them, and this is under regulation.

All permanent houses should be of a material other than wood, and especially the steps where exposed to the weather. A long flight of wooden steps exposed to the weather is especially to be avoided. It is found that buildings not occupied daily for carrying on work are liable to be vandalized to some extent, the locks being used as targets by those of a sporting turn of mind, so that it is well to paint them black or some color not likely to attract attention. The locks on the covers of aqueducts require some attention and should be operated frequently to insure their ease of operation when needed. No windows in this country can long remain without protection.

Culverts require attention, mainly to keep them open, and should be inspected periodically. No plants requiring fertilizers should be placed on the embankments, and they should not be used as pasture ground for cattle. All aqueducts should be patrolled frequently, twice, or oftener, a week. Fences must be built at points where trespassing is especially liable to occur. It is customary to take the heights of water in all reservoirs daily, and in certain cases three times, 7 A.M., noon, and 4 P.M., being

the most convenient. This is of course especially essential where the waste has to be figured from these observations.

Generally, the water level in the reservoirs is kept fairly low in the fall; all flashboards are removed, and preparations made for possible freshets. Provision should be made for as high a flow as would result from $1\frac{1}{2}$ in. over the entire watershed — actual run-off in 24 hours. A little less than this was received on the Sudbury watershed in February, 1886. Flashboards are usually withdrawn by hand, but occasionally machinery is used for this purpose. In vertical dams, i. e., vertical on the lower side, air vibration is sometimes caused in the vicinity while heavy flows are passing over the dam, causing considerable rattling of windows, etc. A cure is generally effected by introducting some object such as a piece of timber or portion of a tree at one end of the dam so as to permit air to enter under the sheet of water.

The computation of yield, waste, etc., is generally done by engineers, and when the water-works man has written his observations, his work on that score is completed. Rainfall observations are also usually made by the man on the watershed as well as temperature readings, usually maximum and minimum daily, and these are often valuable as records for cases in court. Most ordinary gages are of the old type, where the diameter of the circular gage is 14.85 in., making 100 oz. to 1 in. of rain. It would be an excellent idea if a second rain gage were provided on a number of watersheds, so that the rates of rainfall could be measured in heavy storms, not waiting until the morning of the ensuing day before the 24 hours rainfall is weighed. It is also a useful practise to measure the depth of snow on the ground at intervals during the winter, as well as to weigh the equivalent rainfall on the ground at the maximum, so as to know what to expect in case of a freshet in the spring thaws.

Aqueducts should be cleaned perhaps once a year or so, as otherwise the flow is apt to be impeded. The Sudbury aqueduct, about 50 years old, has been found to show what is called a seasonal coefficient of flow, the coefficient increasing in the winter and decreasing during the summer, and if the aqueduct is not cleaned for several years the general line of this seasonal coefficient slowly drops, so that the amount the aqueduct will permit to flow may vary to as low as 85 per cent of a full or 100 per cent flow.

The cutting of grass from the embankments, while sometimes done merely to conform to the neighborhood where trim grounds are the rule, is hardly necessary unless the grass pays for the cutting. Frequently such cutting is only a burden as its cost exceeds its value.

There are various works whose operation require the attention of numbers of men to operate. One of these is the separation of street wash or other surface pollution that it may not enter the water supply without previous filtering. On the Sudbury system the street wash of Natick and also of Marlborough is thus filtered through sand filters built from local

material. In the first case the wash is pumped onto the filter beds, by steam pumps, thence flowing into the water supply. Any water flowing without filtration which might occur during very heavy flows, should be dosed with chlorine before passing into the water supply. Where the necessary pumping can be accomplished by automatic electric pumps it is a considerable advantage. Filter beds may require an occasional "picking up" or "harrowing" to renew their original capacity. In severe winters some trouble may be occasioned by ice on the surface of the water in the beds, and it is sometimes necessary to break up or cut holes in the ice to permit a greater flow. Where any water is removed from the watershed, the one in charge should check all measurements of water so taken, also of any water from outside the watershed, to the end that the net yield may be figured with fair accuracy.

Another of the plants in operation on the Sudbury watershed is the power plant at Sudbury dam, which was built as an afterthought, or installed in the gatehouse nearly twenty years after the dam and gatehouse had been erected. This plant affords a remarkable example of conservation of head otherwise thrown away, and one which yields to the water-works system an annual net profit of over $15 000. All the current is sold to the Edison Company, and as the plant is run as a rule 15½ hours daily, covering their "peak load," it is worth considerably more than what is termed "dump load" which might be turned on or off at almost any hour. I will not detail the features of this plant, as that has been covered elsewhere, but merely suggest a good example to follow for such water-works managers as have considerable head to spare and a market for the resultant electric power. Very few men are required to run this plant, and it is an outstanding example of efficient municipal operation.

In many water-works systems the flow is directly into the mains, so that no adjustment of flow is required, but on the Sudbury system the flow has to be readjusted almost daily, as the receiving reservoir does not permit a large latitude as to fluctuation, and the amount pumped varies considerably. From previous experiment and observation, a known elevation at the head gates results in an approximately certain volume of water going down, corresponding to a known gate opening, consequently it is possible with a few trials to send down the exact amount required. In the case of a second aqueduct, it is required that 24 hours' supply be sent down in less than 15½ hours, i. e., 15½ hours in delivery for 24 hours' use in a reservoir of small capacity, so that care has to be taken that the "peak" of the flow shall not cause an overflow. As the water sent into the reservoir takes 3 hours to travel down from the source, a computation has to be made to prevent overflowing of reservoir. The water being taken out has to be assumed as being drawn at a uniform rate, which is not the case. However, practice in these matters makes errors rare. In covering a holiday or a Sunday, more assumptions have to be made, so that it is not an easy matter to adjust flows under such conditions.

The Metropolitan water is used raw and is presumably free from pollution. Probably the only danger is from bodies of animals or human beings drowned unknown to any one. Happily, so far as we are aware, this has never yet happened.

There are a number of minor points which I will not attempt to cover, such as gages, records, screening, etc., but I would refer to one condition which was brought about by those who built the Sudbury system for the city of Boston in 1875, when a 48-in. pipe was laid for nearly a mile under one of the reservoirs, and was not sufficiently covered to prevent it from floating when the pipe was emptied. When the second pipe was laid it was laid in solid ground outside the reservoir. The first pipe mentioned has floated but once, but such spots in any water-works systems are always a source of anxiety to those in charge. A pipe belonging to a small town which the Metropolitan Water Works supplies on the way to Boston unfortunately has a 14-in. suction pipe which passes under a pond for half a mile, and on three occasions this pipe has floated and broken, causing endless trouble and anxiety to those in charge, as the pond under which it passes is very far from being desirable as a water supply. In the case just mentioned the water was treated with chlorine and it seems now almost self-evident that any water supply where any possible contamination is likely to occur cannot dispense with some means of protection. The cost of a treatment at least of chlorine is so slight, and the escape from serious trouble so very important that the neglect of what might be termed an insurance to at least a limited extent can hardly be excused. There have been cases where, with a sewage plant located near a water supply, gates or pipes in the station have failed or the pumping machinery has broken down, and before relief could be obtained, the sewage has overflowed into the adjacent storage basin. I think it is clear that the officials in charge of watersheds should always be on the alert for any contingency which may involve danger to the water supply, and that when any particular trouble is possible of occurrence at long intervals, that is the very matter for which the official should be on the watch. He should never sleep.

Discussion.

Mr. J. M. Diven.* There is no doubt about the desirability of white pine as a timber, but unfortunately in some parts of the country, in New York at least, white pines have been attacked by the "white pine blister" and even mature pines have been destroyed. This trouble has been so great that the New York State Conservation Commission advise against setting out white pines and are not raising any more seedlings for distribution. About ten years ago the speaker set out 240 000 trees on the watershed at Troy, N. Y.; the young trees — seedlings mostly — were

* Secretary, American Water Works Association.

procured from the state and were supplied at nominal cost. While it may be that the "blister" has not reached New England States, it should be studied and have careful consideration in planning for forestization of watersheds, for sooner or later the blight is sure to reach there unless a remedy for it is found. Currant and gooseberry bushes are now thought to cause or spread the blister and they should be destroyed wherever white pines have been planted. I think they are considered dangerous for a distance of half a mile from the pines.

At Troy, red and Scotch pines were planted mostly and they have been very successful; many trees are now twenty to thirty feet high and all look healthy and vigorous. Some Norway spruce were planted: these have very heavy foliage and spread near the ground, thus forming a good protection from dust and other wind-driven dirt where there is a highway near the reservoir. At Troy these were planted too near the reservoir bank and did not do as well as the pines.

As a watershed protection the coniferous trees are to be preferred to the deciduous varieties, as being evergreen they afford winter protection more than the bare trunks and limbs of the deciduous ones. Many hard woods would be valuable as timber, though mostly of slower growth than the pines. Nut trees, though valuable for both crop and timber, should be avoided on account of the temptation to the small boy to trespass and violate all sanitary rules.

Mr. Winslow. At Framingham we have taken away all the bushes of that sort — currant and gooseberry — from the vicinity of those trees.

Mr. Albert L. Sawyer.* I do not know that I have anything new to offer from what I have said many times before. We are still taking pretty good care of our watershed, and we have practically stopped the boating, fishing, and everything of that sort.

We have been setting out more or less trees for the last two years, — white pine and Norway spruce, obtained from the Forestry Department, — and they have come along very well indeed. In regard to the boating and fishing, the only thing I could say would be that if you want to stop these things you have to keep consistently and constantly at it, and if you do that it has been our experience in Haverhill that you will get the results you are aiming at.

* Water Registrar, Haverhill, Mass.

WORCESTER'S RESERVOIRS, PRESENT AND PROPOSED.

BY GEORGE W. BATCHELDER.*

[*Read September 19, 1923.*]

The water supply of Worcester is collected in nine impounding reservoirs on the hills of Holden, Leicester, and Paxton to the west of the city and furnish a gravity pressure at City Hall of 100 lb. on the low service and 145 lb. on the high service system.

The various steps taken in the development of the reservoir system began with the construction of Lynde Brook reservoir which was completed in 1867.

Lynde Brook dam gave way in March, 1876, and the water rushed down the valley into the Blackstone River causing large property damage but no loss of life.

Water was pumped to the city from Coes reservoir while the dam was reconstructed, which work was completed in 1877.

In 1883 the city constructed a reservoir in Holden called Tatnuck Brook No. 1, this beginning its present low service system. In 1892 this dam was raised ten feet.

In 1895 the high service system became inadequate, so the water of Kettle Brook was taken and carried across to Lynde Brook through a thirty-inch cast-iron pipe. On this system four reservoirs were constructed.

Kettle Brook No. 1 in 1896
Kettle Brook No. 2 in 1903
Kettle Brook No. 3 in 1902
Kettle Brook No. 4 in 1904

On the Tatnuck Brook system there was constructed in 1901 a new reservoir called Tatnuck Brook No. 2. For several years after this no reservoir building was carried on, but in 1911 a long, dry period made it necessary to secure more water. The city, therefore, availed itself of the privilege reserved in the original legislative act allowing the Metropolitan Water Board to take various watersheds tributary to the present Wachusett reservoir and providing that Worcester should be allowed to take for its use what is known as the Asnebumskit watershed. On this watershed there was completed in 1913 Kendall reservoir, and there is now being constructed Pine Hill reservoir.

The water from this shed will be stored in Pine Hill and Kendall reservoirs; part of it will flow from Pine Hill reservoir through an open

* Water Commissioner, Worcester, Mass.

channel about ½ mi. long to the Asnebumskit Head Works, a small reservoir, gatehouse and spillway where water is diverted from the original Asnebumskit brook through a concrete canal 2 700 ft. long to Kendall reservoir. From this reservoir the water is carried through a concrete conduit passing through and under the divide between the two watersheds. This conduit is 1 200 ft. long and 22 ft. under the surface at the deepest part, ending at the discharge pool from which point it flows through an open channel to Tatnuck Brook Res. No. 1, thence to Tatnuck Brook Res. No. 2, from which place it is conveyed to the city in cast-iron mains.

The reservoirs are in two groups, the high service system beginning at Lynde Brook reservoir, from which point all high service water is distributed to the city, and flowing by gravity into this reservoir are the waters of Kettle Brook reservoirs Nos. 1, 2, 3, and 4. The low service reservoirs are located in the manner previously explained. In addition there was constructed in 1895, Parsons low service distributing reservoir located at the same level as Tatnuck Brook Res. No. 2, and supplying a very small part of the low service draft.

The size, area, elevation, storage capacity, and drainage area of the various reservoirs are given in this table:

HIGH SERVICE.

Name.	Area. Acres.	Elevation.	Storage Capacity. Mil. Gal.	Drainage Area. Sq. Mi.
Lynde Brook	132	823	715	2.921
Kettle Brook No. 1	15	845	19	4.098
Kettle Brook No. 2	30.36	988	127	
Kettle Brook No. 3	37.41	1 040	152	
Kettle Brook No. 4	118.61	1 085	513	

LOW SERVICE.

Name.	Area. Acres.	Elevation.	Storage Capacity. Mil. Gal.	Drainage Area. Sq. Mi.
Tatnuck Brook No. 2	52.63	719	257	5.231
Tatnuck Brook No. 1	130	751	729	
Parsons Res.	2.42	719	10	
Kendall	171.82	814	800	2.451
Pine Hill	461	910	3 000	6.899

Upon the completion of Pine Hill dam and reservoir the present watersheds of Worcester will have become fully developed so far as present plans are concerned. Extensive studies have been made of watersheds adjacent to the city to determine the best place for the city to go for a future supply when it becomes necessary.

The available new sources of supply as taken from the last reports are:

Name.	Drainage Area. Sq. Mi.	Approximate Yield. Mil. Gal. Per Day.
Quinapoxet Pond	17.4	10–13
Ware River at East Hubbardston	9.8	8.5
Ware River above Barre Falls	56.1	50
Long Pond, Rutland	7.0	5–7
Turkey Hill Brook	8.9	8
Sugden Reservoir	5.9	5
Stiles Reservoir and Cedar Meadow Pond	7.9	6–8
Seven Mile River above Hillville	7.8	7
Five Mile River at Lake Lashaway	24.7	10–20

The care of the reservoirs is delegated to a foreman who employs during the summer season about fifteen men whose duties consist of cleaning the shores, cutting brush, trees, and general maintenance work. Forestry has been carried on extensively on the watershed areas owned by the city; hundreds of thousands of white pine trees have been planted, and in the main are in excellent condition. Lumbering has also been carried on in a large scale, mature trees have been cut, sawed by the department, using its own men and sawmill, and the product sold. Thousands of cords of wood have been cut within the last two years, much of it delivered to the schoolhouses and the balance sold to various parties.

Worcester furnishes ice water at a large number of public drinking fountains. The last year this ice was bought when prices were 15 cents per 100 lb.; the bills amounted to approximately three thousand dollars per year. The city has for several years been cutting ice for this purpose from one of its reservoirs and putting it in the fountains with its own men and truck. The cost of this work, including every item and 20 per cent annual depreciation on the truck, has never amounted to more than $900.

Three high service cast-iron supply lines run from Lynde Brook reservoir coming together at Webster Square within two miles of City Hall. They are 36 in., 24 in., and 20 in. in size and have sufficient carrying capacity to deliver water at Webster Square without frictional loss. At Webster Square near where the three lines are brought together they again divide into a 30-in. line running to the westerly part of the city and a 16-in. running to the easterly section, which will be shortly reinforced by a 30-in. line.

The low service supply lines are of cast iron, a 48-in. reduced to 42-in. runs within the $1\frac{1}{2}$-mi. circle, this line is paralleled by a 30-in. reduced to 24-in. From Parsons reservoir on the south there runs a 40-in. pipe which crosses the Common in the rear of City Hall, 36-in. at that point and runs that size through most of the congested value district. A gate is closed on this pipe line near Parsons reservoir and is not opened except in case of emergency. During Worcester's most serious series of fires, when twenty-one bell alarms came in during the early morning and day of January 19, 1921, this gate was opened and a low service pressure of 100 lb.

was maintained through the period of heaviest draft. The high pressure system was never lowered below 112 lb., notwithstanding the fact that when the ruins cooled sufficiently so an inspection could be made, a 6-in. sprinkler connection was found broken completely off.

Just a word in closing about Worcester's system of hydrant inspection. During the summer season, hydrants are frequently gone over for the purpose of flushing and for other reasons. When winter comes, this is naturally discontinued and a systematic system of inspection begins. All hydrants in the business district are inspected every two days and those in the residential district every four days. Records of these inspections are kept on a card index system, reports turned in every afternoon and anything found out of good condition is at once remedied.

FILTRATION OF BURLINGTON'S WATER SUPPLY.

BY O. A. CANNING.*

[*Read September 18, 1923.*]

Since Lake Champlain has served Burlington as a source of water supply, many changes have been put in force in order to keep abreast of modern methods of sanitation.

At first raw water was pumped from near the dock. This was found unsatisfactory, and an intake pipe twenty-four inches in diameter was laid, extending two miles westward from the present site of the filtration plant. The water obtained in this manner was likewise distributed through the city mains unfiltered. This condition prevailed from 1894 to 1908. From 1904 to 1908 there were 151 cases of typhoid fever reported.

The State Board of Health, aware that the source of supply was polluted, saw the necessity of filtration, and as a result condemned the lake water as unfit for drinking purposes.

Following this action, filtration of water was begun April 15, 1908, and, for the time being, seemed to halt the spread of the disease; but it was soon proven conclusively that more drastic methods of treatment were necessary. This treatment was continued from 1908 to 1910 and 29 cases of typhoid fever were reported during the period.

In April, 1910, several changes in operation were made, the most important of which was the adoption of a method by which water was treated with hypochlorite of lime. This method was recommended to the superintendent by Hering & Fuller and consisted of dissolving the aluminum sulphate and hypochlorite of lime in one solution, which was applied to the raw lake water as it entered the coagulating basin and allowed to mix for one hour before going to the filter beds. The results were then thought to be satisfactory as the following table shows:

December, 1909 (bleach not used).	
Bacteria in raw water per c.c.	1 072
Bacteria in filtered water per c.c.	62
Efficiency	92 per cent
December, 1910 (bleach used).	
Bacteria in raw water per c.c.	732
Bacteria in filtered water per c.c.	6
Efficiency	95 per cent

The plant removed on an average 95 per cent of the bacteria from the lake water.

In 1911 the general method of operating the plant was completely

* Engineer in Charge, Burlington, Vermont.

modernized. During that year seven cases of typhoid were reported, but six were known to have originated outside of the city.

In 1912 there were	4 cases	
1913	2 cases	(originated outside)
1914	33 cases	(due to milk)
1915	27 cases	(due to milk)
1916	5 cases	
1917	9 cases	
1918	9 cases	
1919	4 cases	(carrier in hotel)
1920	18 cases	(originated outside)
1921	7 cases	
1922	1 case	

In 1921 (November) the last improvement was made. This consisted of installing two Wallace & Tiernan chlorine machines. In this process chlorine is used instead of hypochlorite of lime and up to the present time is proving very satisfactory. We are using 5 lbs. of chlorine to $2\frac{1}{2}$ mil. gal. of water and 1.10 grains of sulphate of alumina per gal.

Following these changes most gratifying results were noted, and much credit for present efficiency of 100 per cent is due to the untiring efforts of Mr. C. P. Moat of the State Laboratory and to Mr. C. H. Jones, ex-Water Commissioner.

Discussion.

Mr. J. M. Diven.* It may be interesting to ask what was the proportion of B. coli in the raw water; whether it was great or not?

Mr. Canning. Well, I think I should have to ask Mr. Moat to answer that question, because I am not a chemist.

Mr. Diven. You do not test for gas producers?

Mr. Canning. Yes, we do.

Mr. Diven. About how do they run?

Mr. Canning. I do not think they average more than one out of twenty in our filtered water. The lake water has coli all the time. We always have gas producers in the lake water; we very seldom get one without.

Mr. M. N. Baker.† When I entered the University of Vermont in 1882 one of the first things I heard about the Burlington water supply was words of caution from the President of the University, who, in accordance with his annual custom, gave good advice to the students about things they should do and should not do. One of his warnings was to be careful about drinking the lake water "until we got used to it."

Some time before the Burlington filter plant was built, I was invited by the city authorities to make a report on the character of the water

* Secretary, American Water Works Association.

† Associate Editor, *Engineering News-Record*.

supply. I dug back through the city reports, and compiled the typhoid statistics for Burlington from an early date up to the time of that report. The showing was rather bad — not as bad as for some other cities of the country, and the indications did not all point to the water supply as the source of the typhoid and of diarrheal diseases. Subsequently the late Prof. W. T. Sedgwick made a bacterial study of the supply, and later on the events occurred which have been so well presented in the paper. Many of the data in my Burlington report were embodied in a paper read before this Association, published in the JOURNAL in June, 1906.

Undoubtedly Burlington suffered for many years from the effect of doing the thing that years ago was so common throughout the United States — discharging sewage into the body of water from which its water supply was taken; and the extension of the intake did not eliminate or entirely prevent water-borne typhoid.

Happily now, Burlington, as the figures you have listened to indicate, is one of a large and growing class of cities in the United States where typhoid has been virtually eliminated. Such typhoid as remains in this city, and in other cities, we all feel thankful as water-works men, is rarely due to the water supply.

MR. R. W. WIGMORE.* I would like to ask if some one can give the cost of chlorinating water?

MR. GILBERT H. PRATT.† To answer the gentleman's question, the cost of the chlorine itself per million gallons varies somewhat with the quality of the water; but as a general average figure, about 50 cents to 60 cents per million gallons is a conservative figure.

Taking the case of Mr. Canning, he said he used about 5 lb. to 2 500 000 gal., which is only 2 lb. per million gallons. Of course I do not know just what their contract for chlorine is, but if they will take their contract price for chlorine plus freight, they will be able to figure their chlorine cost, which would be lower than the figure given, inasmuch as they only require a low dosage treating filtered water.

The first cost is another variable depending on the conditions, but for a round figure, let us say the minimum cost would be $600 per unit, and the maximum cost, according to whether you were working against pressure, as high as $1 500 or $1 600 per unit. By figuring depreciation at 20 per cent you can get your annual charge.

MR. WIGMORE. I might say, Mr. President, that I have an idea, from correspondence I have had with a firm, of the cost of installing. What I wanted to get at was the annual cost of maintenance, covering the cost of the chlorine and the incidental cost of operation. I realize that this cost might differ in certain cases, but the general annual cost of maintenance of this plant per million gallons, is what I was after.

PRESIDENT SANDERS. Will you tell us, Mr. Canning, at what point you apply chlorine to the water?

* Commissioner of Water and Sewage, St. John, N. B.

† New England Representative, Wallace & Tiernan Company.

Mr. Canning. We apply the chlorine to the suction of the pump that pumps the water into the reservoir. Is that what you mean?

President Sanders. Yes. Did you state what the capacity of your reservoir was?

Mr. Canning. I did not; but I can. We have two reservoirs. One has a capacity of 4 000 000, the other 3 000 000 gal., a total of 7 000 000 gal. which we have for reserve on the hill. Our water is not all pumped direct to the reservoir; it is pumped into the mains and the overflow goes to the reservoir.

President Sanders. Do you have to pump 24 hours out of the day?

Mr. Canning. No, we do not. At different times of the year it varies a little. At the present time I think we are running about 16 hours out of the 24. Our capacity is about 2 500 000 gal. in 24 hours, and our chlorine machine is set for 5 lb. per 24 hours' run.

President Sanders. What is the capacity of the pumps?

Mr. Canning. Two and one-half million gallons in 24 hours, that is, a little over 1 600 gal. a minute.

President Sanders. Do you have more than one pump?

Mr. Canning. Yes. Each one has that capacity.

President Sanders. Do you ever run both pumps together?

Mr. Canning. We never have. We just use the second one as an auxiliary.

President Sanders. Then, you have a very constant use of the water, so that you can figure right down to a fine point just the amount of chlorine that you use in the water?

Mr. Canning. Yes.

President Sanders. You do not have any variable amount?

Mr. Canning. Practically the same. It is the same from day to day unless we change the controller arm. We always run it practically the same; we do not vary it more than perhaps a half pound, or something like that.

Mr. Diven. I think the gentleman from St. John can easily work out the cost of the chlorine and the original cost of the plant, and the depreciation. But with his gravity system he would probably have to have an expense which would not come in the pumping plant with its attendance. He probably would have to have an entirely separate force of men to look after the chlorination, make daily analyses and attend to the apparatus, which would not be required with the pumping plant.

Mr. Wigmore. That would depend on the location. If our chlorine plant was set at practically the source of supply, it would be necessary to have some attendant there; but if it was established along the line, say six miles from the general distribution, why, we have a man there now. So that it is just a question of where the proper location would be.

Mr. Pratt. Along that line which Mr. Diven raises, I would like to raise one point, if I may. That is, with the automatic equipment, which

would be the type to use in the case Mr. Wigmore is speaking of, it would not necessitate constant attendance, but it would require at least a daily inspection. Of course the apparatus would automatically vary the flow of gas as the flow of water varied in the main. So that it would really be the same old question that anything automatic has got to be looked after, and it would be a case of where somebody would go around every day and inspect it.

I just thought I would correct any possible impression there might be that it would require three 8-hr. shifts, or anything of that kind, to watch it.

Mr. Caleb M. Saville.* If I tell what we do in Hartford about this matter, perhaps it will clarify the situation a little and possibly give the gentleman some light on the subject.

We have a gravity supply, and while we have filters and do not use much chlorine we do use enough to keep the gas machine turning over, as it were, for use should there be an emergency and the filters were put out of use.

We have a filtered water basin which has perhaps a head of 25 ft. on that portion of the pipe where a Venturi meter is located. Right at that point we have a chlorine gas house in which are located both an automatic device and a manually-operated device, so that if anything is wrong with the automatic machine the manually-operated one would be in service. Attached to these are four cylinders of chlorine gas in service all the time. We put in from one-tenth to two-tenths of a part per million — just enough to keep the machine in service. A man goes to this plant at least once each day, among his other duties, usually twice each day, — once in the morning and once in the afternoon, — to see that everything is working all right. That is all the attendance that is required.

Of course the amount of chlorine that is put in is shown by the register and the amount of water that is passed through is shown on the Venturi meter. The chlorine gas cylinders are set on scales, which are read every day and the amount of chlorine that has gone in, is thus known and checked against the amount which the automatic register shows.

Taking what the gentleman said about the Burlington supply, — if I remember it correctly, — I think Mr. Pratt said that it would be about 30 cents for the chlorine per million gallons pumped. That is for the chlorine inself. Mr. Pratt, I think, also gave a maximum figure of something like \$1 500 or \$1 600 for the cost of the plant. If you write that off in five years, there is about \$300 a year to write off every year for the plant. Dividing the \$300 per year by the total million gallons that is used per year gives you the cost per million gallons in plant. Then if you put a man on there and let him go around, I suppose you would allow an hour or two hours of his time on each day for his attention to the chlorine. Those

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

added to the cost of the chlorine used will give fairly near the cost per million gallons for your plant.

Does that answer your question?

MR. WIGMORE. Yes, sir. Thank you very much.

MR. BAKER. I might say that many years ago there was installed, up by the reservoir — apparently so long ago that those now in charge of the water works have forgotten it — a high service pump driven by the hydraulic pressure in the main delivering the water into the reservoir. This pump delivered water to a tank at a higher elevation, supplying a limited high service area. It was an interesting and unique piece of automatic high service pumping machinery. The installation was described in *Engineering News*, October 1, 1887.

ELIMINATING WATER HAMMER FROM A HIGH-PRESSURE REGULATING VALVE.

BY SYDNEY LEE RUGGLES.*

First a bit of history. The Barre Water Company, a private corporation operating under the "Goodhue" patents, was organized in 1886 to supply water for domestic, sanitary, and fire-protection purposes to the city of Barre, Vermont, and the system was installed in 1887–1889. The supply was taken from the Jail Branch of the Winooski River by the construction of an intake dam about two and one-half miles from the city, and at an elevation approximately three hundred and forty feet above the business portion. Trouble was soon experienced from typhoid and other intestinal diseases due to the fact that the considerable town of East Barre was situated not far above the intake dam. The State Board of Health condemned the source of supply and it was abandoned as soon as possible.

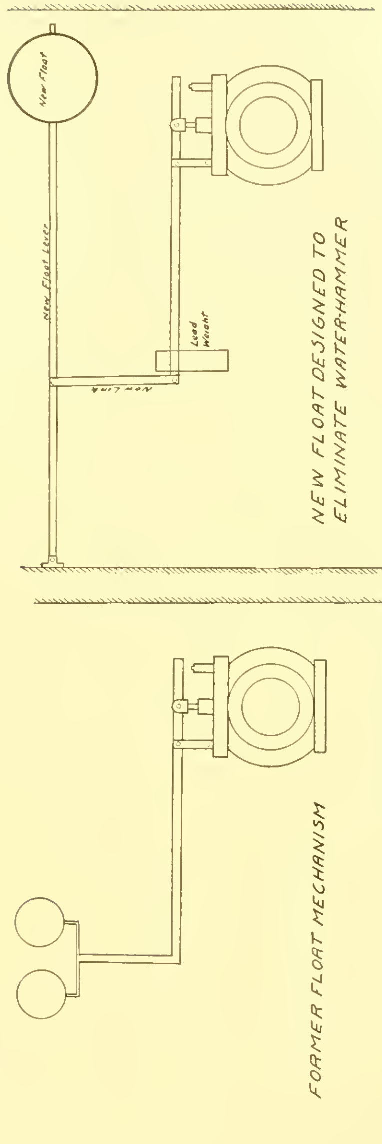
In 1897–8 a new supply known as the Bolster was developed by a main running along the Barre-Williamstown road which tapped two brooks, but this was soon found inadequate and the Water Company resorted to pumping from the Stevens Branch of the Winooski, which was nearly as bad as the Jail Branch, since it came through the village of Williamstown. The city took over the plant in 1898 and immediately extended the Bolster main to tap a third brook in the town of Williamstown known as the Martin Brook. Even this did not furnish an adequate supply and pumping from the Stevens Branch was continued.

Acting under the advice of Freeman C. Coffin and other engineers, the city constructed a line of pipe about three miles long from a point on the pipe below the old dam of the original Barre Water Company on the Jail Branch to a mill site on a branch of this stream in the town of Orange, and by the construction of a gravel filter used this supply for six years.

In 1910 a storage reservoir of about forty million gallons was constructed just below this milldam from which the present so-called Orange Supply System is taken.

As the new Orange Reservoir is about five hundred and eighty-five feet above the city, and the old one eight feet higher, the resulting pressure head if piped directly to the city would be about two hundred and fifty pounds, an almost prohibitive figure. Accordingly the original 16-in. line of the old Barre Water Company was cut just below their dam and a chamber which we know as the "Reducing Chamber" built over the pipe. To this was piped the lower end of the Orange extension which was reduced from a 24-in. pipe at the dam to an 8-in., and an 8-in. regulating valve

* City Engineer and Superintendent, Water Department, Barre, Vermont.



8" REGULATING VALVE AT BARRE, VT

installed at its entrance to the chamber. The original valve as designed by Mr. Coffin was a simple flap valve operated by a large float and a walking beam mechanism. This was replaced in succession by balanced valves of three different types, none of which have been satisfactory. The size of the chamber itself is much too small, being 6 ft. 6 in. by 9 ft. in area and about 5 ft. 6 in. deep. This inadequate area gives such a rapid fluctuation in water level that the valve is constantly working. Successive superintendents have pointed out this defect and recommended a larger chamber, but the City Council has as regularly turned down the project.

The valve is working under a pressure head of 272 ft. on one side and 3 ft. on the other and has to stop or start three miles of water. The lever arm of the float operating the valve was about three and one-half feet and the valve closed with a rise in the water level of about six inches. Under this combination of circumstances severe water hammer was to be expected and was realized. Sometimes as many as seventy-five leaks in a season developed between the valve and the reservoir, and in the spring when the frost came out of the ground the repair gang would have from two weeks' to a month's work recalking blown joints.

Apparently the only method used by previous superintendents to relieve the water hammer was to adjust the stop bolt on the regulating valve so that the valve could not completely close and thus cut down the water hammer to a safe degree. This meant, however, that at night a large amount of water was wasted over the spillway in the chamber, a dangerous loss in time of low water.

On coming to Barre three years ago to take the supervision of the Water Department, I was introduced to the Reducing Chamber by the retiring superintendent, who said that it was one of the nightmares of our position. He explained this method of control, which worked very well (aside from the waste of water) for short intervals. But a few months' bumping of the check bolt would wear it down, and soon reports of a leak or two in the road would be brought in. Overnight these would develop into half a dozen. We would then adjust the stop again and would have comparative peace for a few short weeks.

Having been a teacher for ten years before going into practice, I began to put my training in mechanics to work after some months' experience with this chamber. In the first place I recommended the installation of a relief valve which was purchased and installed two years ago. This cut down the effect of the water hammer, but did not strike at the source. The water in the pipe would often pulsate more or less regularly and the relief valve would blow off every few seconds.

Then I turned attention to the regulating valve and worked out a new float control. I ordered a new float 12 in. in diameter and 24 in. long and a new lever of such length that when hinged on the side of the chamber opposite the regulating valve the float at the other end would nearly reach the opposite wall. I removed the original small floats, but kept the original

lever. A little calculation of the lever arms showed where to drill the new lever arm so that a link hinged at this hole and attached to the end of the old float lever would multiply the lever ratio by about three and one-half, which was the ratio between the available rise and fall of the new float and that of the original one. This meant that the water had to rise nearly two feet to close the valve instead of about six inches, and solved the problem, as it now closes so slowly that nearly all water hammer is eliminated.

There was still one difficulty to be remedied, however. Although the regulating valve was of the balanced type with water admitted at both top and bottom at the same time to equalize the pressure, there seemed to be an unbalance at a certain point in closing. When this point was reached the valve closed suddenly with a decided kick, the pressure jumping instantaneously sometimes as much as sixty pounds. As observation showed that this kicked the lower or original lever upward, I hung about two hundred pounds of lead on the outer end next to the link connecting the two levers, eliminating that kick effectually.

The proof of the pudding? In two years we have had six small leaks. When the frost came out of the ground this last spring three small leaks were evident in three miles of pipe. I sent up three men who dug up and recalked all three leaks in one day, where formerly it would sometimes take a month each spring to repair damages.

THE CAUSE AND EFFECT OF RANGE-BOILER EXPLOSIONS.

WILLIAM A. BRADFORD.

[*Read November 13, 1923.*]

I had the honor, as well as the pleasure, of speaking before your Association in December, 1915, and February, 1916, on this same subject. At that time I tried to demonstrate by the use of lantern slides, and the talk which I gave, the probable cause and effect of range-boiler explosions. I also gave a practical demonstration of the unreliability of many of the so-called "water relief valves," which were then upon the market, when placed in practical use, also demonstrating that they were not dependable when an emergency arose.

One of the other features, and what to me seemed a very important one at that time, was the necessity of the enactment of certain legislation which would require the manufacturers of range boilers to meet the requirements and conditions, as well as the strength and capacities, for which their boilers were sold. This also applied to tanks and other vessels which were to be used for the storage of hot water.

At that time boilers were being sold to the plumbers, and installed by them, the capacity of which was anywhere from 10 to 25 per cent less in actual test than the manufacturer's stated capacity of the boiler. The strength of the boiler varied anywhere from 15 to 40 per cent less than the indicated tested strength which was generally stamped upon the side of the boiler by the manufacturer.

I had already introduced in the Legislature a bill to try to remedy the existing conditions, and asked for the support of the members of your Association for the passage of the bill. The bill did not pass that year, but I pursued the same policy and introduced the bill again, and it was passed in the succeeding year. The passage of this bill was not a panacea for all the existing conditions, but it was the first step in the right direction, and carried such powers of enforcement with it that the inspectors of plumbing within their respective cities and towns shall cause the provisions of the act to be enforced. Many of the inspectors in various cities took cognizance of this fact and require that the plumbers in the installation of boilers for the storage of hot water live up to it in its entirety. I fear, however, that in many other cities and towns the inspectors have failed to take advantage of what was useful and necessary legislation.

It would seem, Mr. President, that this is the psychological time to point out to the members of your Association, especially those who reside in Massachusetts, that they could be of great service to the public, municipalities, and the plumbers as well, by striving to have this law strictly enforced in the communities in which they live.

I have no desire to use valuable time on those things which are past, but I do wish to point out briefly to you exactly what the law does and could accomplish with closer coöperation. The following is the old and also the amended law.

MASSACHUSETTS BOILER LAW

Arrangement of the Old and the *Amended or Revised Massachusetts Boiler Law

Old Law General Acts of 1916, Chapter 154.
Amendment General Acts of 1917, Chapter 39.

Acts Relative to the Marking, Sale and Installation of Range Boilers.

Be it enacted, etc., as follows:

Section 1. No range boiler shall be sold or offered for sale in this commonwealth, unless its capacity is plainly marked thereon in terms of Massachusetts standard liquid measure, together with the maker's business name, in such manner that it may easily be identified.

Section 2. No copper, iron or steel pressure range boiler, whether plain or galvanized, or other vessel or tank in which water is to be heated under pressure, shall be sold or offered for sale in this commonwealth without having stamped thereon the maker's guarantee that it has been tested to not less than two hundred pounds hydraulic *or hydrostatic* pressure to the square inch, together with the maximum working pressure at which it may be installed. And no such boiler, or other vessel or tank in which water is to be heated under pressure, shall be installed if the working pressure is greater than forty-two and one-half percent of the guaranteed test pressure marked thereon by the maker.

Section 3. Any person who sells or offers or exposes for sale any range boiler which is not marked or stamped as provided in the preceding sections, or which is falsely marked as having a capacity which is greater by seven and one-half percent than its true capacity, or who marks or causes the same to be marked with such false capacity, shall be punished by a fine not exceeding fifty dollars for each offence. The inspectors of *plumbing within their respective cities and towns shall cause the provisions of this act to be enforced.*

Section 4. This act shall not apply to the sale or offering for sale of installed range boilers or to the sale or offering for sale of range boilers as junk.

Section 5. This act shall take effect on the first day of July, nineteen hundred and seventeen. (Approved March 1, 1917.)

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*Author's Note: This has been arranged to show both the old and revised law. The part in italics refers to the part amended.

Various tests and experiments were made by me, as shown in Table 1, to determine if possible the variances between the rated and the actual strength and capacity of many of the standard makes of both copper and galvanized range boilers.

In Fig. 1 the two boilers at the right clearly indicate the variances in strength and capacity of range boilers of both copper and galvanized iron previous to the enactment of the Massachusetts Boiler Law (General Acts of 1916, Chap. 154). The figures shown on the boilers were charted after making the tests previously referred to, and indicate that copper and galvanized-iron boilers were then being sold of a capacity of from 15 to 25 per

TABLE I.

Number of Test Maker of Boiler Style	No. 1 Dahlquist Competition	No. 2 Dahlquist Full 30	No. 8 Dahlquist Guaranteed	No. 3 E. B. Badger	No. 4 Hayes Mfg. Co. Modern	No. 5 Galv.	No. 6 Moriarty	No. 7 Star Regular
Number of Test	No. 1	No. 2	No. 8	No. 3	No. 4	No. 5	No. 6	No. 7
Weight of boiler empty	42 lbs.	54 lbs.	56 lbs.	44.5 lbs.	49.5 lbs.	64.5 lbs.	59 lbs.	25 lbs.
Weight of boiler full of water	252.25 "	309.0 "	316.0 "	288.5 "	300.0 "	286.5 "	303.0 "	283 "
Weight of test equipment	58.00 "	69.5 "	72.25 "	61.0 "	66.0 "	81.25 "	76.0 "	41 "
Weight of water in boiler—Net	194.25 "	239.5 "	243.75 "	227.5 "	234.0 "	205.25 "	227.0 "	242 "
Temperature of water at test	44° F.	44° F.	43° F.	44° F.	44° F.	44° F.	43° F.	43° F.
Rated capacity of boiler	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.
Actual capacity in gallons by weight	23.45 "	28.85 "	29.24 "	27.29 "	28.2 "	24.72 "	27.35 "	29.15 "
Boiler minus rated capacity	6.55 "	1.15 "	.76 "	2.71 "	1.8 "	5.28 "	2.65 "	.85 "
Actual weight of boiler—stripped	42 lbs.	54 lbs.	56 lbs.	44.5 lbs.	49.5 lbs.	64.5 lbs.	59 lbs.	25 lbs.
Actual outside circumference	35.125 in.	37.75 in.	37.5 in.	37.25 in.	27.75 in.	36.25 in.	36.75 in.	37.5 in.
Actual height of straight side	54 "	$57\frac{5}{8}$ "	59 "	54 "	$54\frac{3}{8}$ "	58 "	56 "	59.5 "
Actual height of dome top	$3\frac{1}{4}$ "	$3\frac{1}{2}$ "	$4\frac{1}{2}$ "	5 "	5 "	$1\frac{1}{2}$ "	$4\frac{1}{2}$ "	$1\frac{1}{2}$ "
Form of top head	Flat oval dome	Round dome	High round dome	Round oval	Enlarged round dome	Flat oval dome	High round dome	Flat dome
Form of bottom head	Flat	Flat	Bulged out	Bulged 1 in.	Bulged out	Dented in	Flat	Flat
Circumference equal to diameter of	11.2 in.	12 in.	$11\frac{7}{8}$ in.	$11\frac{7}{8}$ in.	12 in.	$11\frac{9}{16}$ in.		$11\frac{7}{8}$ in.
Theoretical capacity (As per above measures)	26.46 gal.	29.38 gal.	30.5 gal.	27.765 gal.	29 gal.	25.52 gal.	30 gal.	
Capacity by drawn off measure by Sealer of Weights & Measures		28.89 "	29.88 "					
Factor used by weight—1 gal. =	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.
Factor used by capacity—1 gal. =	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.
Actual weight of one gallon by Sealer of Weights & Measures	8 lbs. 5 oz. 2 dr. 19 gr.							
Expressed decimally, lbs. per gal.	8.323 lbs.							
Allowance by Tolerance for 30 gal.	27 cu. in.							

cent less than that for which they were rated, and that their tested strength was from 10 to 40 per cent less than that stamped or marked by the manufacturer on the side of the boiler.

The boiler at the left shows clearly, in an enlarged form, how the boilers must be marked now to comply with the law, and if a boiler is sold for a 30-gal. boiler it must hold within $7\frac{1}{2}$ per cent of its rated capacity as marked, or exactly 27.75 gal. If the boiler is rated as a 200-lb. test boiler it must be stamped that in effect, and guaranteed to work under a constant pressure of $42\frac{1}{2}$ per cent of its tested strength, which would mean that a boiler so marked would be suitable for use under 85 lb. working pressure.

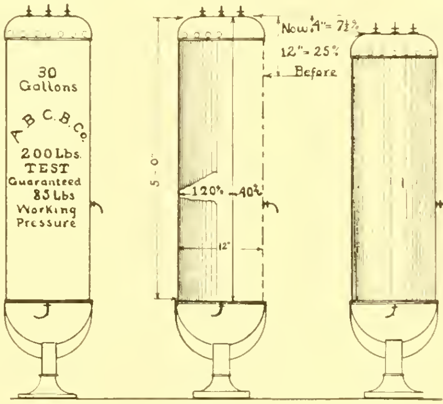

FIG. 1.

This seems like the logical time to make the line of demarcation between the type of installation which is called a " cistern pressure boiler " and the so-called " pressure system." The former is supplied from a tank in the attic from which it derives its head or force, the same tank acting as a receptacle for the expanding water in the boiler while under heat, or for the superfluous water caused by expansion.

In the latter, or pressure, system, the tank receives its supply of water direct from the city main through the service pipe and consequently is subject at all times to approximately the same pressure (less the difference in height) as exists in the main.

Fig. 2 illustrates, and affords as well, an opportunity to make a comparison between the two systems. In actual operation the principle is the same in both cases, except the difference in the higher elevation of the tank, reservoir, or standpipe shown at the extreme top right-hand corner of the drawing. This higher elevation creates additional pressure and the boiler which is supplied under this head of water must of necessity be of heavy construction, and is called a " pressure boiler." The elevation of the reservoir which is 200 ft. above the boiler is equal to approximately 86 lb. pressure per square inch.

The boiler shown at the left is supplied from a tank in the attic, or the upper part of the building. In former times this tank was called a cistern, and from this fact we derive the name of "cistern boiler" for this particular type of low-pressure range boiler. In this instance the cistern or tank is 25 ft. above the boiler, and the head of water is equal to a pressure of approximately 10.85 lb. per square inch.

We labor under the impression that water is a great conductor of heat. Nothing could be more erroneous. Water itself is a great insulator and nonconductor, but on account of the mobility of the molecules of which it is composed, circulation is easily set up and maintained when heat is

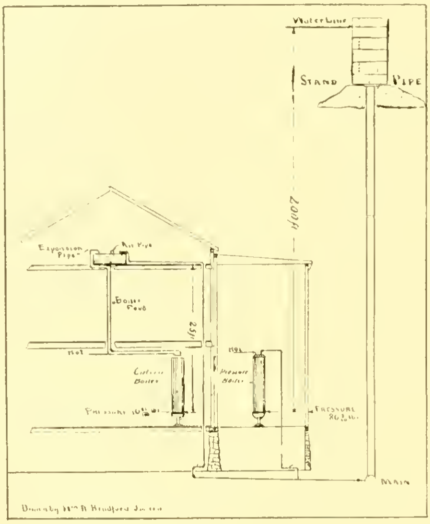

Fig. 2.

applied. Water, when heated, expands and becomes lighter, volume for volume, and it is due to the difference in density or specific gravity in two like columns of water, that it may be set in motion and circulation maintained.

Under a rising temperature from 60 degrees to 212 degrees, the boiling point of water at atmospheric pressure, a given quantity of water will expand approximately $^1/_{25}$ of its bulk. If the water is confined in a bent tube shaped like the letter "U," both sides being of equal length, and heat is applied near the lower portion of either tube, water will expand in one tube to a higher elevation, particularly on the side to which the heat is applied. If the original height of each column of water in the tube is 25 in., and the extreme temperature as stated above, was obtained, then the height of the water in one tube would be approximately 26 in. If a connecting tube is applied horizontally between the two perpendicular tubes, at the original height of the water before it was heated, then the water which is at

a higher level in one tube will flow through the connecting tube into the other tube and create the motive power or additional head which will start the circulation of water through both columns as a consequence of their having been thrown out of equilibrium. When small single tubes are used, in either a horizontal or perpendicular position, a partition called a diaphragm is generally arranged in the center of the tube to insure circulation and prevent confusion between the ascending and descending columns of water.

The principles involved in the circulation of water and other fluids when confined in vessels are clearly shown in Fig. 3, which illustrates a

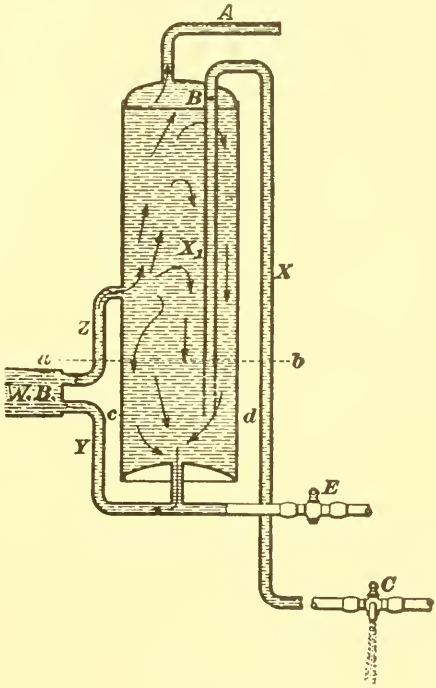

Fig. 3.

sectional view of a pressure boiler and the usual system of piping connected thereto. Note the cold-water service pipe X, and how it extends down into the boiler to a point about one foot from the bottom. This is the usual arrangement and shows that the pipe X outside of the boiler becomes the long leg of a siphon. When stop C is closed and water is allowed to escape through the waste hole, water is siphoned directly from the boiler and a vacuum is bound to occur in the boiler.

To prevent the formation of a vacuum a hole is made in pipe X at a point inside the boiler about six inches from the top. This is called a sniff hole, and is supposed to allow air to enter pipe X at point B and break or

relieve the vacuum. It can readily be seen that such relief cannot be obtained until the water at the top of the boiler has been reduced to the level of the sniff hole B, even though you open a faucet on the hot-water distributing pipe A. Should you not open a faucet on pipe line A, which would allow air to enter and further relieve the siphon, then the sniff hole is of no consequence and water will continue to siphon from the boiler through pipe X, wasting through the drainage hole in stop C, and create a more severe vacuum in the boiler. The same effect is obtained, only more quickly, when the water is shut off in the main and drained, or when, as very often happens, a street main or supply pipe suddenly breaks, unless due precautions are taken to prevent the formation of a vacuum in the boiler. The greater the vacuum in the boiler the more severe the collapse as a consequence of the atmospheric pressure being continuously in force at all points on the outside of the boiler. If a complete vacuum could be created inside the boiler, to crush it in the atmospheric pressure bearing on the outside of the boiler would be equal to approximately 15 lb. per square inch of exposed surface, hence the use of the vacuum valve.

Undoubtedly the vacuum valve was placed on the market earlier than the water relief valve. Carr's vacuum valve was probably in use 35 or 40 years ago. Other opinions to the contrary, I still believe that its proper location is attached to the cold-water feed pipe, directly over the top and as close to the boiler as possible.

To be of service a vacuum valve must operate instantaneously. The velocity with which air will enter a complete vacuum is equal to 1 320 ft. per second. This is 1.4 times faster than a stream of water would be discharged under the same pressure from a pipe of equal diameter. Vacuum valves, to be efficient, must be free from mechanical parts, springs, and so forth, and operate at the lowest possible pressure. Mechanical devices in vacuum valves, when used singly or when used in combination with a water relief valve, are partly the cause of their failure to operate when required to do so.

When a vacuum valve is required what could be simpler or more practical than the ordinary brass check valve? In the case of a top check or lifting check valve, the disc will be lifted from its seat under a very slight pressure. There might be some objection to this particular type of valve, as there is a possibility when the disc and seat are both of metal that they might cohere or adhere to each other. There is a possibility of residue collecting on the seat of the valve which would prevent it from closing tightly.

In the swing check valve I believe we have none of the objectionable features which I mentioned in connection with the top check valve. Furthermore, the valve could be arranged in a diagonal position so that the slightest amount of atmospheric pressure on the reverse side would cause the clapper to which the disc is attached to swing quickly inward, allowing the air to enter before a vacuum could be created. Moreover, for the purpose of determining whether the valve was in working order the disc could

be pushed from its seat by inserting anything of small diameter into the inlet end of the valve.

But, why all this worry, when for a few dollars more on the initial cost of the boiler, copper boilers can be obtained which are guaranteed against collapse, and for a more modest expenditure, a good grade galvanized-iron boiler may be used, which is not only noncollapsible, but on account of being built of heavier and stronger material, is better able to withstand the strain of excess internal pressure?

I have used a little more time than I intended in describing the cause and effect of a vacuum in and on range boilers, believing it would be of interest to the members of this Association, inasmuch as many of the complaints for damage to boilers from this cause are brought to your attention as superintendents of the water works in your respective towns and cities. Let us now turn to the two more dangerous conditions under which range boilers and other vessels in which hot water is stored under pressure have to operate, namely, excessive pressure and temperature.

Modern methods of living, and modernized plumbing, have brought about more insistent demands for instantaneous hot water, and the main idea to-day seems to be to produce these results by cutting down the storage capacity of the boiler and providing an excessive amount of energy in the heating agencies by substituting in place of the old cast-iron water front with its typical connections based on 50 sq. in. of heating surface for a 40-gal. boiler, brass water fronts and brass coils in the stove, auxiliary gas water heaters of intermittent and instantaneous types, tank heaters of both brass and iron excessive in size, and lastly, the introduction of brass coils into the fire pots of furnaces, steam and hot-water heaters, used for house-heating purposes.

The pressure system of hot-water supply is here to stay and we may as well recognize that fact. Modern sanitary conveniences require that the flow of hot water be equal to that of the cold. In order to accomplish this it is necessary that both hot and cold-water supplies be installed to work at approximately the same pressure. Hence the so-called " pressure system " of domestic hot-water supply. It has often been advocated that we return to the old method in which the boiler receives its supply from the cistern or tank in the attic at a much lower pressure, but the modern construction of buildings does not permit of doing this, and of course in high buildings, such as office buildings, and so forth, the pressure on the boiler would be approximately the same, whether supplied from the city main or from a tank at the top of the building.

On a pressure job, with all valves and faucets tight, the system is under a constant pressure equal to that in the cold-water service pipe. When a faucet of the compression type is opened the pressure is reduced; when closed, the system again returns to its normal pressure. The only relief for the expanding water from the boiler would be back into the main. Should anything prevent its egress, then an additional amount of pressure would be created within the system.

With a Doherty Self-Closing Bibb, when excess pressure was created, it would overcome the tension of the spring and force the disc from its seat, thereby relieving the pressure. I have in mind an actual occurrence where the range boiler was excessively heated, and the plumber condemned some faucets of this type because he claimed they leaked, when in reality they were only striving to relieve the excess pressure that had been generated in the domestic hot-water supply.

The Bashlin Bibb, although of the self-closing type, would afford no such relief as the one previously described on account of the fact that the greater the pressure generated in the system, the tighter the disc would be driven against the seat.

The Quick Closing Fuller Bibb would also act in the same manner. When the lever is released the ball is driven more tightly on to its seat because of the conical shape of the ball washer with the larger area on the pressure side.

The relative infrequence of explosions when we consider the multiplicity of copper pressure range boilers in use in this territory, is undoubtedly due, in part at least, to the following fact, namely, that it is very seldom a ball cock is absolutely tight. Assuming that there was an obstruction in the supply to the boiler on account of a check valve, or a pressure reducing valve, having been placed in line of same, or the pipe having become stopped or plugged up, I am confident that relief from additional pressure would be obtained through the ball cock, provided of course that there was one connected with some part of the plumbing system in the building or house. This statement should not be construed to mean that relief from excessive temperatures in the domestic or other hot-water systems could be obtained in the same way.

I carried on experiments and found that with a certain type of compression ball cock, with a 5-in. float under a hydraulic test, the cock would open at a 120 lb. pressure, and discharge exactly 227 grains of water, equal to 1 oz. avoirdupois. I tried this 10 times with the same result each time.

Substituting a 6-in. for the 5-in. float, it required 130 lb. pressure to overcome the resistance of the 6-in. float. This statement checks up with the fact that on one occasion a certain gas company, in making repairs, shut off the supply to the house without reducing or checking the heating of the range boiler, and as a consequence, hot water was drawn from the closet tank when it was flushed.

With a "Dececo" Rotary Ball Cock it was necessary to apply a pressure varying from a 140 to a 145-lb. before relief could be obtained when a 5-in. float was used on the ball cock. When a 6-in. float or ball was used on the same cock it required a 150-lb. pressure to overcome the flotation of the ball. This particular style of ball cock possesses the feature of closing more quickly than the other.

A plumber living in the vicinity of Boston who has given this matter

considerable study tries to arrange the piping in the building so that there will be a separate or independent supply to the range boiler, having the theory in mind which I have just described. Into the boiler feed supply he connects a branch pipe to supply the ball cock on the nearest closet tank, with no shut-off or other obstruction in either line.

That we all may have a better understanding of this subject I am trying to show the pro and con of every proposition. The ball cock, called the "Novelty," would not function in an emergency like those which I have previously described, because the seat is a movable, hollow tube, and when once seated on the disc of the ball cock, excess pressure on the supply side would have no effect upon it whatever.

On other occasions when I spoke to the members of your Association I stated my belief that the only panacea for the troubles about which we are talking would be a rigid supervision and inspection of all installation and piping in connection with this work. As briefly as possible I desire to show a few of the dangerous defects due to faulty construction and installation which I believe, had they been subject to inspection, would not have been permitted or used.

When a pressure water regulator, oftentimes called a pressure reducing valve, is used on the house supply or the cold-water supply leading to the range boiler there is absolutely no chance for the expanding water in the boiler to find relief. The accumulated pressure on the house side of the regulator is used as a motive power, functioning on a diaphragm of large diameter to overcome the initial pressure of the service pipe. Hence, the greater the pressure on the house side the tighter the valve will close. In a sense it becomes a check valve and prevents the outward flow of water, and consequently should never be used except in conjunction with a reliable water relief valve, especially with a closed or pressure system of hot water.

A subscriber to a trade paper writes, "Will you please advise me of the different methods now in use to prevent hot water from range boilers getting back into meters by expansion or by siphonage? I am quite familiar with putting a hole in the conducting tube, but that will not always overcome the difficulty. Suppose the boiler be suspended from the cellar joists and connected with a coil in a furnace. The regulations here require that a check valve shall be placed between the meter and the boiler, which I consider a dangerous practice, and as yet have never done it, as there would be no chance for expansion. Am I right? The meters here are easily spoiled by hot water, as the pistons are made of hard rubber."

Yes, he is right. The writer has found that they have a law compelling the use of a check valve, to be placed between the meter and the boiler. It seems most absurd that the superintendents of water works should insist on such installation without also requiring that relief valves be placed in the same line of pipe between the boiler and check. It has

been suggested that a small hole could be drilled through the clapper of the check valve, but this in time would become clogged. This would render such an arrangement useless.

Catalysis in iron pipe has without doubt been the cause of many bursting boilers. It is a fact that, even up to the point of complete stoppage, some water will find its way through a corroded or stopped pipe, but inversely, when expanding water seeks egress back through a pipe clogged with corrosion or catalysis, it acts very similar to a swing check valve and prevents its free passage.

I wish to make a brief résumé of some of the tests which I have made in the last few years on various so-called "water relief valves." I have picked out these few at random from a great many that I tested.

There is nothing new in the idea of using water relief valves on pressure boilers. As early as 1880, 43 years ago, the Carr Valve and other valves similar in design, with lever and weight attachments, were on the market. This design of valve has been condemned for use on both low and high-pressure steam boilers in this state. Any one may tamper with the weight and unknowingly increase the load by the slightest movement of same from 15 to 25 lb. On one occasion a plumber was called to a house to replace a boiler that he had installed a short time before. The boiler was leaking and the valve had previously leaked, and to stop it, the lady of the house had hung a flatiron in addition to the weight upon the lever.

On an American Steam Gauge Relief Valve the lever acts diametrically opposite to the one previously described. In action, the end opposite the fulcrum is lowered instead of being raised. It would be an easy matter, in case of leakage, to stop further action of the valve by propping it tight with a stick, one end resting on the floor and the other under the lever.

A view of the Ashton Relief Valve in section would lead you to believe that its construction is mechanically correct. My comment would be that there are too many metal and mechanical parts to it. One of these valves was set at 100 lb., and after 2 years' service it was tested and found to blow at 240 lb.

The Ryan Relief Valve is a combination vacuum and relief valve, probably the first valve that was ever made for use on this type of work having a soft metal or lead disc. As made, this feature would have been of no consequence, as lead fuses at approximately 620 degrees, F. After one of these valves was in use a short time it was removed and tested. It blew at 380 lb.

In a Mueller Relief Valve (small screw, $\frac{3}{8}$ in.), the restricted waterway makes the valve of little consequence. In fact, many of the towns and cities will not permit the use of a relief valve in which the waterway is less than $\frac{1}{2}$ in. The V-shaped arrangement of disc and seat should condemn it. One of these valves was set at 90 lb. It was in use less than two years. It was tested when taken off and found to blow at 280 lb.

I am glad that the Mueller Company redeemed themselves by placing their Diaphragm Relief Valve upon the market. Conversely, the operation would be almost identical with the pressure reducing valve, and you can readily see how great a motive power could be generated under the diaphragm of the valve in case of an emergency to assist in raising the disc from its seat. Comparing the diameter of the disc and diaphragm the relative value is about one to twenty-five. I wish that I had time to tell you a story about a plumber who placed one of these valves directly in the supply to the range boiler, so that the water had to pass through it in order to reach the boiler.

As stated before, the Boston Self-Closing Bibb would afford an automatic relief for excess pressure in the hot-water system, it being required that only enough pressure be generated on the under side of the disc to overcome the tension of the spring, causing the disc to rise from its seat. The chief objection to the use of a self-closing faucet is the sudden shock or strain thrown upon the system of piping when the handle of the faucet is released.

The repeated shocks or recoils from water hammer when self-closing faucets are used are deleterious to the system of piping, and when copper range boilers are used, have a tendency to weaken the material and mechanical construction of the boiler.

Undoubtedly with a knowledge of these facts in mind, Stack designed his Combination Faucet and Relief Valve, eliminating the objectionable features already described. When in ordinary use, it is operated the same as the lever-handle compression bibb.

When acting as a relief valve for excessive hot water, the excess accumulated pressure overcomes the tension of the spring and causes the disc, which is movable, to rise from its seat, allowing the accumulated water to escape and relieve the pressure. When used as an ordinary faucet, the frequent use of same is an assurance that the disc will not stick or adhere to the seat as it is moved with each operation of the faucet.

In Fig. 4 you have an optical demonstration of the breaking of a copper boiler while under pressure. The boiler was equipped with a water relief valve set at 100 lb. The boiler had the manufacturer's stamp on the side stating that it had been tested at 200 lb. The boiler burst at 140 lb. cold-water pressure.

There is nothing new about the so-called pressure or closed system of domestic hot-water supply. When it originated undoubtedly the pressure in the water mains and supply pipes was much less than that required to-day, and galvanized-iron boilers were used on pressure systems almost entirely. It was not unusual in cities where the pressure was low, to draw hot water from the hydrants in the street, at least I have been told so by men older than myself, who should know. This would indicate that the natural relief for expanding hot water is back into the main, and personally, after 35 years' experience in the plumbing business, I cannot

understand in these enlightened times, why any one should desire to prevent it.

In raising the temperature of the water in a 30-gal. boiler from 60 to 212 degrees at atmospheric pressure, there would be discharged from the boiler theoretically every minute, assuming 1 hr. is required for this change of temperature, a slug of water of approximately 5 in. This, multiplied by 60 minutes, would equal 300 in., or 25 linear ft. of water in a 1-in. pipe. Under ordinary conditions, with the heating surface of the water front properly proportioned in relation to the boiler it served, the expanding water would cause no injury to the meter. The troubles that we have

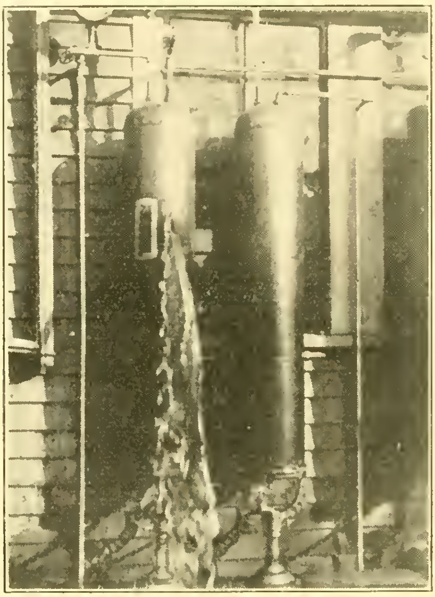

Fig. 4.

had, and are still experiencing, are due, as previously stated, to excessive heating of the boiler, and consequently a larger volume of expanding water from the boiler. This trouble could be regulated by efficient inspection.

I have heard it said that a water meter was so constructed that it acted as a check valve and prevented back pressure. If I am correctly informed I do not believe that this is so. Although the mechanical parts of a meter might become disarranged or enlarged on account of expanding hot water, I do not believe it possible for this condition to become so acute that the inlet and outlet ports of the meter would be entirely blocked. Would the cost of constructing meters that would withstand hot water be prohibitive? I have been told that a certain city had water meters constructed so that the meter, itself, constituted a check valve, and as a

result of the damage caused to properties in which the meters were installed, it is the defendant in several suits.

If a check valve is introduced into the main supply pipe of the house for the protection of the water meter, what assurance will be given the house owner that his home, as well as the lives of his family and himself, will not be placed in jeopardy? Can it be possible that a man representing a city would do what I heard one superintendent say when I spoke before your Association previously, that he would insert the check valve and the owner must look out for himself?

I have been told that many of the superintendents of water works still persist in their idea that a check valve should be placed in the line of supply to the boiler in order to prevent hot water from the boiler expanding back through the meter. The illustration following represents a fact and not a theory. I, personally, made the installation shown in Fig. 5, with

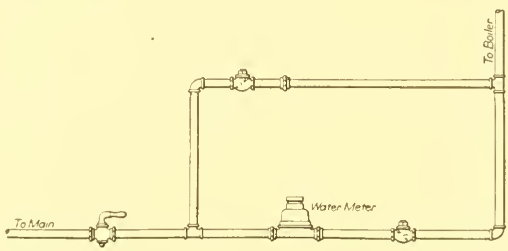

FIG. 5.

the permission and under the direction of a superintendent of water works who is a member of your Association. Briefly, when the boiler was fired in its usual manner, and the main shut-off closed, and the top of the upper check valve removed, hot water from the boiler expanded back and over the top of the check valve at regular intervals.

With the top of the check valve in place, and the shut-off open, the click of the check valve could be heard at regular intervals as the expanding water from the boiler passed through it. The clapper of this check valve was arranged to swing outward or towards the pressure. The clapper of the lower check valve was arranged to swing inward towards the boiler. At no time during the test did hot water pass the lower check valve. Both check valves were of the swing check pattern.

At the time I made the test just referred to I did not know of the patented device called "the Protector." I have no idea what the cost of this device would be to-day, but if it will protect the meter (and that seems to be the chief desire of many of the superintendents), and allow the expanding water egress into the mains, it is an assurance against boiler explosion, and a cheap investment at any price.

Few of us realize the small amount of water required to generate a tremendous volume of steam. In comparison, it is said that 1 cu. in. of water, when evaporated into steam, is equivalent to 1 cu. ft., or 1 728 cu. in.

At a temperature of 215 degrees a pound of steam is equal in volume to approximately 27 cu. ft. At 100 lb. pressure the temperature is equivalent to 337.5 degrees, and 1 lb. of steam occupies approximately 2 cu. ft.

This will give you some idea of the terrific force expended when the steam is allowed to escape through a rupture in a boiler. I doubt if many of you comprehend the tremendous pressure to which the average range boiler is subjected. At 100 lb. pressure, the total surface pressure which it is required to withstand, is equal to 195 400 lb., and this does not include the top and bottom heads of the boiler.

Time does not permit of my dwelling on the spheroidal state, but I am strongly of the belief that this phenomena obtains under certain conditions, and especially in the copper coil of a gas heater, and the water front or brass coil of a range, when they are under pressure and overfired, with an inadequate supply of water.

A majority of the range boilers are constructed of too light material. Even the apparently strong galvanized-iron boiler is not immune from this defect. Table 2 shows some tests on three galvanized-iron range boilers and at what pressure a permanent set was placed in the head of one of the boilers. Occasionally a galvanized boiler, strong as it appears to be, explodes.

TABLE II.

RESULTS OF TESTS MADE BY WM. A. BRADFORD, QUINCY, ON 30 GALLON 12′ x 5′ MASSACHUSETTS REGULATION RANGE BOILER.

TESTS MADE ON MARCH 22, 1917, AT RIVERSIDE BOILER WORKS, INC.

Manufacturer	Weight	Height Over-all	Height On Shell	Inside Diam.	Outside Diam.	Gage Shell	Tested to	Remarks
John Woods Mfg.	52 lbs.	$62\frac{1}{8}''$	$60''$	$12''$	$12\frac{1}{16}''$	12	230 lbs.	*
W. B. Scaife Co.	95 lbs.	$61\frac{3}{4}''$	$60''$	$12''$	$16\frac{1}{16}''$	12	200 lbs.	†
Riverside	101 lbs.	$62\frac{1}{2}''$	$60\frac{1}{2}''$	$12\frac{1}{8}''$	$12\frac{3}{8}''$	11	230 lbs.	*

DISH OF BOTTOMS

Wood $3\frac{1}{8}''$ Riverside $3''$ Scaife — Bottom concave and convex shape. $1\frac{1}{2}''$ in at rim, $\frac{1}{2}''$ out at center.

TEST ON RIVERSIDE DOUBLE EX. HVY. KOPSTEEL BOILER.

This boiler is a 300-pound test, $127\frac{1}{2}$ pounds working pressure Massachusetts Regulation boiler, shell 10 gage, bottom $\frac{3}{16}$ inch, made of copper steel, and carries a time guarantee of six years.

Weight $120\frac{1}{2}$ pounds. Dish of bottom $2\frac{3}{4}$ inches. Tested to 300 pounds plus. At 300 pounds there was not a hair bulge to bottom.

* Bottom did not bulge a hair.

† At 120 pounds moved out slowly $\frac{1}{16}$ inch. Between 160-180 came out $\frac{1}{8}$. At 200 pounds total bulge $\frac{3}{16}$. Bottom was permanently set.

In Massachusetts the district police have jurisdiction over construction and inspection of both low and high-pressure steam boilers when used in public buildings, halls, factories, mercantile buildings, and so forth. The safety valve on low-pressure boilers is set to blow at 15 lb. pressure. On high-pressure boilers the valve is set in proportion to the strength of the boiler.

In both cases the valve has a lock-up attachment so that it cannot be molested. Each boiler is provided with a fusible plug, gage, and water cocks. Before the boilers can be operated it is necessary to obtain a permit from the district police after the boilers have been inspected and found to comply with the necessary laws and regulations. This permit must be renewed, after certain requirements have been complied with, each year. Certain rules are laid down by the Board of Boiler Rules governing the tensile strength, thickness of plates, joints, type of rivets, and general construction of the boiler.

I have cited all these conditions because in the manufacture of copper and galvanized-iron pressure range boilers no such laws prevail, and yet the element of danger in the use of the average kitchen pressure range boiler, with its varied heating attachments, is ten times greater than that of the safeguarded wrought and cast-iron steam boilers.

The city of Boston has recently put into force an ordinance making it compulsory to install pressure, temperature, and vacuum relief valves on all new boiler installations in the future. I find no provision in this ordinance for safeguarding the installations which are already in use. In my estimation, this ordinance or law is of no particular value. I find no provisions incorporated in the law for its enforcement.

I will now describe some of the relief and temperature valves of more recent design and manufacture. The Donnelly Water Relief Valve may be adjusted by the plumber and then locked up. This is not a good practice. The valve should be set at a certain pressure by the manufacturer before it is installed, and so locked or sealed that it could not be molested afterwards. I have been told that the Boston Ordinance was based on the principles involved in this valve.

The Red Top Relief Valve is one of the later models and seems to be an innovation for this type of work. The Boston Ordinance as drawn says, "The valves can have no interior weights, and must be of such type that the plumber must adjust them to the pressure required on the job." I fail to see how this valve can qualify, although the same company makes a valve of larger design with movable or adjustable weights in which the power of resistance may be increased or decreased. My personal objection to this valve would be the possibility of the spindle or stem sticking in the guides and at the seat. A type of valve similar to this has become obsolete, at least in this state, on steam-boiler installations.

Donnelly's Temperature Valve is distinctly a temperature valve, and pressure has no bearing upon it whatever, except as it affects temperatures. Its action would be identical with an ordinary fusible plug, except that the

composition of the metal should be such that it would fuse at a lower temperature — for safe practice, not exceeding 225 degrees.

The Smith Temperature and Water Relief Valve, in my estimation, is a distinct innovation, and a step in the right direction. The lower fusible plug which is the first to fuse and relieve excessive temperature, melts at approximately from 215 to 220 degrees. Instances have come to light where the plumber boastfully stated that after the valve blew, to save the householders further annoyance, instead of inserting a new fusible plug, leaving the valve in order for the next emergency, he wilfully plugged it with a wooden plug; but the inventor has tried to make the valve foolproof, and about halfway up on the tube of the valve there is another fusible plug which the plumber cannot molest as easily, and which melts at approximately 240 degrees. The pressure relief feature is near the top of the valve and is contained in the upper chamber. The tension of the spring holds a fiber disc washer on the seat of the valve except when overcome by excess internal pressure.

Quite recently I spent two days with the inventor of the Smith Valve, testing this valve. In every instance the valve did exactly what was claimed for it. The results of the most interesting test, no relief valve attached, open system, are as follows:

Time, 3.30, temperature 60 degrees, pressure 45 lb.

Time, 3.42, temperature 285 degrees, pressure jumped from 45 to 50 lb., instantly. Hot water was forced back through the feed pipe seeking relief, and pressure dropped to 45 lb.

Opened Bibb, first, a flush of hot water from 6 ft. of $\frac{3}{4}$-in. pipe to empty it. Then it blew steam from 15 to 20 sec.

I also make these deductions after witnessing the tests:

First. That water heated to above 180 degrees is a waste of gas.

Second. That flow pipes from heaters should not be less than $\frac{3}{4}$ in. in diameter to prevent waste of gas, as the velocity of the water through pipes of smaller diameter is not fast enough.

Third. That boilers of greater capacity and heating agents of less energy should be used; that is, they should be more carefully proportioned, one to another.

Fourth. Drip or waste pipes from relief or temperature valves should be vented by an open tee end or sniff hole close to the valve connection to prevent siphonage of water from boiler when valve is open.

Gentlemen, in conclusion, let me say that the element of force evident in all boiler explosions, and the possibilities contained in any boiler heated under pressure, are greater than those of gunpowder, nitroglycerin, or TNT. Limited time permits of only briefly qualifying this statement. Water heated under 20 lb. pressure in a 30-gal. boiler, if given an opportunity to expand or flash into steam, will equal 4.75 per cent of the contents, equal to 11.1 lb. of water, equal to a volume of steam of 298 cu. ft., equal to 914 000 ft. lb. of energy let loose.

One pound of black powder, if exploded, would develop 960 000 ft. lb.

of energy. Change the pressure of the water in the boiler to 70 lb. pressure, and increase the other factors in their respective ratio, and a ruptured boiler would then liberate 2 642 000 ft. lb. of energy.

One pound of nitroglycerin, if exploded, would liberate 2 000 000 ft. lb. of energy.

Why do boilers explode?

First. Excess pressure from expanding water causes a rupture in the boiler at its weakest point.

Second. The sudden release of the energy confined in the boiler as it expands blows the building asunder, enough power remaining in the boiler to blow it from its former location as though it were a projectile being discharged from a gun.

Did you ever notice the absence of water in a room where a boiler explosion had occurred?

I will end this talk with these conclusions and suggestions:

First. That laws should be enacted placing the installation of this type of work under the direction of the District Police, Department of Public Safety.

Second. Installation of work should be made only after a permit has been issued, and at its completion the work should be inspected.

Third. Each pressure and cistern boiler should be equipped with a vacuum valve.

Fourth. Each pressure hot-water boiler or tank should be equipped with a water relief and temperature valve, with lock-up attachment, but so arranged that they can be operated without changing the adjustment.

Fifth. No obstruction should be placed in the feed pipe to boilers to prevent expansion of water from the boiler or in the circulation pipes of the boiler.

Sixth. The amount of heating surface should be regulated in proportion to the capacity of the boiler.

Seventh. A thermostat automatically controlling the supply of gas should be used with all gas water heaters when attached to hot-water boilers.

Eighth. The size of tank heaters, when used in conjunction with hot-water boilers, should be regulated and equipped with automatic devices controlling the draft of the heater.

Ninth. The manufacture of pressure range and other hot-water boilers and tanks should be under the supervision of the Department of Public Safety.

Tenth. Any other reasonable laws and regulations safeguarding existing and future installations of boilers on this class of work should be enacted.

If a course were pursued similar to that which I have described, with the assistance of your Association, the district police, the Master Plumbers' Association, the Heating and Power Engineers' Association, and the coöperation of the gas companies and boiler manufacturers, I am sure that we could obtain results, and at least try to prevent by supervision the frequent explosions of range and other hot-water boilers.

TOPICAL DISCUSSION.

Standardization of Water Meter Registers.

[*September 20, 1923.*]

President Sanders. Mr. Hawley, will you start the discussion on water meter registers?

Mr. W. C. Hawley.* I came here to get some information on this subject. I do not know that I can give very much.

A year ago last summer while my family was away I went home one evening and discovered a postal card under the kitchen door, left there by the Natural Gas Company, with the statement that the inspector could not get into my house to read the meter and requesting that I indicate on the dials printed on the postal card the positions of the hands, and mail it to the office. It struck me as a pretty good scheme. I made some inquiries of the gas company and found they were getting about 75 per cent of their "pick-ups" by this method, instead of having to send a man back in all cases to get the reading.

I thought that would be a good thing for water meters, and I started to get some cards ready. I did not realize until then what a difference there is in the registers of the various makes of water meters, and not only in the various makes, but in some cases in the registers of different meters made by the same company. I finally did get up cards. I gave up trying to reproduce the registers. I identified the different dials by the 10, 100, 1 000, 10 000 figures, and so on, and we have been using cards of that kind very satisfactorily. I was able to get them down to three; one card for the "straight reading" registers, then another card to fit the "Hersey-Nash-Keystone-Pittsburg Disc and Arctic" meters, and another card for the "Gamon, Worthington and Trident."

But that called to my attention the difficulty which our meter readers encounter as they go about reading meters, — the difference in direction of the rotation of the hands, the difference in the arrangement of the dials, etc., — and it seemed to me that if there could be a standardization of the meter registers it would eliminate a great deal of trouble and perhaps many mistakes. Of course it could not be done in a month or a year; it would take a long time, but we have standardized the threads on fire hydrants, though it is going to take a long time to get the standard generally adopted, and it seems to me that this is a thing that is worth trying.

I have discussed the matter with various other gentlemen, and those with whom I have talked seem to think that it is worth while to take this matter up and see if the registers cannot be standardized.

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* Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

Mr. J. M. Diven.* You took this matter up with the Joint Committee on Standard Specifications for Water Meters. How did you come out with them?

Mr. Hawley. I did, but unfortunately the matter was not brought to their attention until I guess the report was pretty nearly agreed upon. At any rate, they decided it was not advisable to take it up at that time, I believe.

Mr. Caleb M. Saville.† I would like to say that while the final report of the Joint Committee was submitted to the American Water Works Association at its convention in May, and the report was accepted by the Association, the committee of the American Water Works Association on this matter was continued for the purpose of considering just this matter, and I don't know what action the New England Association has taken in this connection. Perhaps the Association here would like to take some action on it, because it seems to me it is a very important matter. The meter manufacturers, as I understand, are very willing to coöperate in any reasonable way, and I believe something of this kind could be worked out in time just the same as the standard specifications have been worked out.

Mr. David A. Heffernan.‡ I would like to ask Mr. Hawley if he made inquiries in regard to the practice of sending out these cards. If he did not, I would suggest that he write to Mr. Kingman at Brockton. They have been using them for some time.

Mr. Hawley. We have been using these cards now for some time ourselves, and we get about 50 per cent of our readings with the cards.

Mr. Joseph A. Hoy.§ The same practice has been going on for a number of years in Worcester. Mr. Batchelder at the present time has put out cards indicating the round registers or the oblong registers, for the parties to indicate on the cards their meter readings. It has been a practice in Worcester for a number of years to use some kind of cards.

President Sanders. How does he allow for the different makes of meters?

Mr. Hoy. He has one card for the oblong readings and one for the round readings.

President Sanders. Are there any members here from the Manufacturers' Association that would care to say anything on this subject?

Mr. Charles W. Sherman.|| If Mr. Blanchard were here he would be best fitted to speak for the manufacturers' committee.

President Sanders. I think we would be glad to hear from Mr. Blanchard.

* Secretary, American Water Works Association.

† Chief Engineer, Board of Water Commissioners, Hartford, Conn.

‡ Superintendent, Water Works, Milton, Mass

§ Foreman, Water Works, Worcester, Mass.

|| Of Metcalf & Eddy, Boston, Mass.

Mr. W. K. Blanchard.* The standard specifications for cold-water meters — disc, crest and compound type — have just been completed, and it is a question whether or not it would be advisable at this time to carry on any further standardization work.

The question of standardizing water meter registers has been taken up not only in the discussions held among the manufacturers, but also in the joint committee meetings of the New England and American Water Works Associations. The situation regarding water meter registers is this:

There are eleven different types of registers, round reading, having location of digit wheels in different places. In some of the cases the hands on the digit wheels *all* turn clockwise; while, in most of the registers, the hands of the round reading registers alternate in turning clockwise and anti-clockwise for the different digits.

Another point is that in some of the registers the unit digit or test dial is located on the top of the register, while, in other registers, the unit digit is located at the bottom of the register.

In some cases the increase from units to the higher digits occurs in an anti-clockwise direction, while in other cases, the unit digits to the higher digits occur in the clockwise direction. Thus it is seen that there are a multiplicity of combinations now being made and in use on round reading type of registers.

Whatever standardization on registers that might occur should be done by the joint committee of the two Associations, as, if the manufacturers endeavor to use a standard construction, a considerable amount of complaint would be received on account of the change from the register which has been supplied and used for many years.

Speaking for the Manufacturers' Standardization Committee, would say that the problem has already been gone into and has been found a difficult one for solution. The manufacturers, however, would be very glad to coöperate at any time with the Associations and extend hearty coöperation to them.

In the case of the larger meters, say, over 1 in., there is a still more difficult problem. However, in case of the large size meters, it is assumed that you would want your meter man to read these meters anyway. Therefore, it is the registers of the domestic meters that you would be most concerned in standardizing.

In most manufacturing plants, where large meters are installed, they are almost always accessible, and the meters can be read and should be read by the meter reader because it is a good thing to look over a meter at least as often as a man reads it, whether it be every month or every three months.

Speaking for the manufacturers, I can assure you that whatever the New England and American Associations want done, they will have the hearty coöperation and support of the Meter Manufacturers.

* Assistant Secretary and Engineer, Neptune Meter Company.

Mr. Sherman. I hardly know what to suggest in view of my not being absolutely certain as to what the action of the Association was, but perhaps it would do no harm to pass a vote that will enable us to straighten out the matter if my recollection is right, and it will do no harm if it is not.

I therefore move that the Executive Committee be authorized to reappoint or revive the Association's committee to work with the corresponding committee of the American Water Works Association on Meter Standardization, if in its judgment it seems wise to do it.

(The motion was duly seconded and carried.)

TOPICAL DISCUSSION.

Use of Brass Pipe for Services.

[*September 20, 1923.*]

President Sanders. The next subject is the "Use of Brass Pipe for Services." In these times when we are getting so much trouble with red water, and using cement-lined, wrought-iron and steel pipe, I think that a discussion of this subject is a very proper one, especially at the Superintendents' session.

Mr. David A. Heffernan.* There are so many good pipes and materials used for services to-day, I am going to put it this way. I think the brass pipe in cost is prohibitive.

Mr. J. M. Diven.† I have been giving considerable attention to this matter. The cost of brass pipe, heavy brass pipe, is about the same as 2-A lead pipe. Pure copper pipe, which probably has some advantages over brass, is about the same as 3-A lead pipe. Now, that hardly seems prohibitive, because I think lead pipe of those weights is being used quite generally. I think in a majority of places — I don't know about New England, but through the Middle States and Western States and the Middle West, lead pipe is being used more extensively than anything else. Now, as to any cheap material, if the cheap material is not long-lived, I believe the cost of digging up the paved street and renewing the service would be prohibitive.

Mr. R. W. Wigmore.‡ A few years ago we put in a few services of galvanized pipe and their life was not over seven years. We have lead pipe which has been in use between sixty-five and seventy years, and in many cases it is just as good to-day as it was the day it was laid.

Mr. Caleb M. Saville.§ When the gentleman says seven-year-old galvanized pipe, he probably means galvanized-steel pipe and not galvanized wrought-iron pipe.

Mr. Wigmore. Yes, that is steel.

Mr. Saville. It has been the experience that galvanized-steel pipe will last in the neighborhood of six or seven years, but you do not get into trouble with galvanized wrought-iron pipe for fifteen to eighteen years. We have some old wrought-iron pipe in service that has been in service forty years.

Mr. Wigmore. This is steel I spoke of.

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* Superintendent, Water Works, Milton, Mass.

† Secretary, American Water Works Association.

‡ Commissioner of Water and Sewage, St. John, N. B.

§ Chief Engineer, Board of Water Commissioners, Hartford, Conn.

Mr. Diven. There is another consideration with the cement-lined pipe, and that is soil corrosion. You are back to iron pipe as far as the action on the outside of the pipe goes.

Mr. Heffernan. I would like to have the members go to the Union Meter Company's table at the exhibit hall, and you will find a section of pipe taken out in the city of Worcester. It is cement-lined pipe that was laid in 1865, and the pipe is in good condition. The interior is perfectly lined, and hardly any corrosion on the outside.

Mr. Joseph A. Hoy.* The piece of pipe that the Union Water Meter Company has on exhibit was taken out of a service in the city of Worcester about two years ago. It was installed in 1865 and was one of the first services. There is very little outside corrosion on it, and the cement probably looks as good as the day it was put in.

At the present time we are using small steel pipe, 1-in. lined to $\frac{3}{4}$ in., costing about 12 cents per ft.; and $1\frac{1}{4}$-in. lined to 1 in., costing about 15 cents per ft.

Mr. Sydney L. Ruggles.† I want to raise the same question Mr. Diven has already done. My experience in replacing old services has been that we get more corrosion on the outside of the pipe than on the inside, and most of the leaks that we have had to repair in the old services have been due to the fact that the outside had rusted away. There may be a difference in water, although most of our services have been in about thirty-five years. They are evidently wrought iron, because you can see the characteristic of the structure. But they would go a good many more years with no trouble from the inside. I do not know how lining them with cement would affect them.

Mr. Diven. They could be protected on the outside with cement.

President Sanders. The custom in my city, with a private owner — our water is very soft and will fill up a galvanized pipe, wrought-iron or steel, in a period of about eight to thirteen years — is that almost every one in the city now, when they replace their services, use brass pipe. We lay the service from the main to the street line, and they are practically all using brass pipe from the street line to the inside of the cellar wall.

Mr. Bristol. What size?

President Sanders. Three-quarters of an inch. We take an inch pipe and reduce it to $\frac{3}{4}$ in., and then they will lay a $\frac{3}{4}$-in. brass pipe to the inside of the cellar wall.

Mr. Bristol. Is that large enough for these automatic valves that they are now using without tanks on toilets?

President Sanders. No, I hardly think so.

Mr. F. N. Speller.‡ It may be unwise to get started on this subject, because it is one that ought to take a whole evening, but we have heard a

* Foreman, Water Works, Worcester, Mass.

† Superintendent, Water Department, Barre, Vermont.

‡ Metallurgical Engineer, National Tube Company.

great deal lately in popular advertising about the virtues of brass pipe, and of course we recognize its advantages. But we hear nothing at all about the weak points of brass, and I think an engineer naturally wants to hear both sides of such a question.

Of course I am speaking in a very general way on this subject. We all know that all kinds of metal are subject to corrosion. All common metals are subject to corrosion in various kinds of water. Lead, for instance, has been used since the time of the Roman Empire, and yet to-day it is legislated against in some places on account of the effect of certain kinds of water. They would not think of using it with some water, but it gives good service with others. And that is also true of copper. It is inadvisable to use copper in salt water — hot salt water especially.

Brass pipe has been used for some time, although not nearly as widely as you might think. The annual production according to the most reliable data available does not exceed 20 000 tons. The tonnage of steel pipe amounts to 2 500 000 tons. So that while brass is a factor, it is an expensive pipe with limited uses.

Now, brass pipe, like all the other metals, will last well in some waters, and in other waters there is a peculiar kind of disintegration that none of the other metals are subject to, for the reason that brass is an alloy, whereas copper, lead, iron, and steel are elementary metals. This peculiar disintegration which occurs in certain places is probably due to the fact that the alloy is not uniform, so that you get an electrolytic effect which results in the solution of the zinc, leaving a residue of copper, the result being a heavy loss in ductility and strength of the metal. This occurs particularly at the couplings, because the coupling materials are cast brass, which is a different composition from the drawn pipe. The result is disintegration and weakness at the root of the thread and a liability to break off at this weak point. There have been to my knowledge twenty or thirty instances of this in my native city of Pittsburgh, and I know that it has occurred to a serious extent in other cities, both in hot and cold-water lines. Now, that is not condemning brass pipe for all purposes, because there are other localities where this does not occur, and where one may safely use brass pipe if you want to pay the price. So also there are many localities where galvanized-iron and steel pipes do not corrode seriously. But, on the other hand, steel, as we all admit, has a high degree of ductility and strength. It is the strongest pipe of all, and for service lines the inside can be protected from corrosion by a cement or lead lining. The cement lining was developed in New England where it has been used for 50 or 60 years. Means are now available for removing the oxygen economically from water which will stop corrosion of any metal.

The outside of the pipe can be protected by a number of means, where protection is required. The bituminous coatings, and especially those that are reinforced by saturated fabric, are not used nearly to the extent they might be used. The gas companies have gone into this subject in

detail and have developed suitable protective coatings for use when such are needed.

In closing I just want to add this in taking issue with Mr. Saville in regard to the iron versus steel question. As he knows, I do not agree with him at all in his statement; no definite evidence on the superiority of wrought iron has been submitted. The fact that one line lasts 30 or 40 years and another line lasts perhaps half that time does not prove anything at all. Conditions have everything to do with corrosion. There is this to be said, however; that engineers have recognized the fact that corrosion is largely a question of external environment, and in order to get a comparison you must have the two materials together in service under the same environment. On that basis, during the last 20 years there are on record many tests made by independent engineers in water lines, where pipes were put together carrying the same water, and where the tests were run to destruction. The results show no difference between iron and steel on the average; sometimes a little difference one way and sometimes the other. But on the general average there is no difference at all.

Sometimes we hear of a case where a service line has been in use for a number of years, when the line is taken up and a piece of modern pipe — no matter whether it is iron or steel — is put in. Perhaps this pipe gives trouble in half the time, and this circumstantial evidence is used against the more modern pipe. But in the meantime many factors may have changed. For example filtration plants may have been introduced, and it has been found that the protective coatings, formed by deposits of inorganic and organic materials on the surface of the metal have a great deal to do with retarding corrosion. Now, if these natural protective factors are lacking and you put new pipe in with clear filtered water that has lost its power of protecting the metal, what is going to happen?

Mr. Heffernan. There is one element which I think has not been considered, and that is the electrolytic action or galvanic action. I would like to ask the former speaker that, if in his judgment, if the brass pipe tubing is a somewhat different alloy than the fitting, would there be more chance for corrosion than there would be with the wrought-iron or steel pipe and fittings. The reason I speak of this is because I have had considerable experience in connection with electrolytic action; that is, from the grounding of wires on the pipes. We have found from experiments that the telephone and the electric grounding on the water pipes has caused galvanic action. This has had a very bad effect indeed on the pipes. Now, this is a subject for discussion that is going to be continued at some time in this Association. As I understand it, Mr. Diven, the American Association went on record as allowing the grounding of telephone and electric wires on their pipes.

Mr. Diven. Alternating current. That was following the action of the National Board of Fire Underwriters.

Mr. Heffernan. Probably most of you gentlemen have read in the

papers of a case in the city of Newton where copper pipe was substituted for brass pipe in the bathroom, and when the water was used the sponges turned green. It was looked into and experiments were made, and the result was that the trouble was traced to the grounding of the wires on the pipe. An insulating joint was inserted on the house side and a further test was made, and the green substance on the sponges disappeared.

Now, this is an important subject, and a joint committee is appointed from the American and New England Associations to make a further study. I am a member of that committee, and I hope in the near future that we can get together and get some information on the subject.

PROCEEDINGS.

NOVEMBER MEETING.

CITY CLUB, BOSTON,

Tuesday, November 13, 1923.

The President, David A. Heffernan, in the chair.

MR. CALEB M. SAVILLE. Mr. President, I would like to make a motion that this Association put on record an expression of its sympathy with Mr. Charles W. Sherman in his illness, and also as a practical mark of its appreciation of his services to the New England Water Works Association that the President and Executive Board be authorized to send flowers to Mr. Sherman with the compliments of the Association, and as a reminder of the loss the Association feels in his absence from this meeting.

(The motion was duly seconded and unanimously carried.)

A paper on " Cause and Effect of Range-Boiler Explosions," illustrated with the stereopticon, was delivered by Mr. William A. Bradford, Quincy, Mass.

Mr. W. K. Flavin of Boston read a paper, illustrated with the stereopticon, on " Problems the Flush-Valve has Solved and Others it has Created."

Adjourned.

FRANK WELLINGTON HODGDON.

Frank Wellington Hodgdon died at Arlington on January 26, 1923. He was born in Arlington on January 12, 1856, attended its schools, and graduated from the Massachusetts Institute of Technology in 1876. His entire professional life was devoted to the service of the Commonwealth, which he entered soon after graduation as engineer of the Harbor Commissioners in 1876. Throughout all the subsequent changes in the organization of the state department having to do with the harbors and public lands of the Commonwealth he continued in the same line of service for a period of forty-seven years. The list of the improvements in the lands and public works of the Commonwealth carried out in accordance with his designs and under his direction is a long one and includes the extensive improvements made in Boston Harbor and the estuaries about it within the last half century, and especially in recent years. The great Commonwealth dry dock, the largest in the United States and second largest in the world, was built after his designs and under his direction.

In addition to his work upon the harbors of the Commonwealth he was active in the reclamation of lands from the inroads of the sea and was early connected with the measures for the improvement of the Province lands where an effective work has been done in preventing the shifting of the sands in the region north of Provincetown. The work of inducing a growth of vegetation capable of thriving upon these areas has resulted in gradually reducing them to stability and has removed conditions which had become a serious problem. He was appointed in 1897 a member of the commission on a topographic survey map of Massachusetts charged with making a survey of the municipal boundaries, and later on when this commission was merged with the Harbor and Land Commission he completed the town boundary work in 1915. This work is of great and permanent value and will furnish the foundation for an accurate map of the state and its cities and towns, a great need in a state so densely populated as Massachusetts. In connection with the town boundary surveys he had charge of the surveys and re-marking of the state boundaries bordering Rhode Island, Connecticut, and New York, and was a special commissioner upon establishing and marking the boundaries between Massachusetts and the states of Vermont and New Hampshire.

In connection with the work of his department he prepared the reports and estimates for the proposed canal from Taunton to Boston and was also consulting engineer on the Cape Cod Canal. His engineering activities were not confined to the limits of Massachusetts. On account of his ex-

tended experience in such matters, he was appointed in 1911 by President Arosemena to represent Panama on the commission of engineers on the Costa Rica-Panama arbitration. He was also in charge of the improvements of the Florida coast-line canal from St. Augustine to Key West and was consulting engineer in connection with other similar developments.

He always took an active part in the work of the various engineering societies and was interested also in the International Association of Navigation Congresses, of which he was a member.

In his home town of Arlington he played a leading part in public affairs, giving his time freely to a great variety of committees having to do with public improvements and public interests in general.

His thorough knowledge of everything pertaining to harbors and waterways and their development and protection, united with a firm courage, sound judgment, and a most agreeable personality, made him invaluable as an adviser in all matters relating to such subjects, and because of these qualities his advice was in constant demand by legislators and others having to do with such questions. Faithfulness to the service of the state and unswerving loyalty to its interests and to the highest ideals of his profession leave a record of public service rarely equalled in his time.

X. H. Goodnough.
F. A. McInnes.
Committee.